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CHAPTER 11 Lasers in the Treatment of Vascular Lesions

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Lasers in the Treatment of Vascular Lesions

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KEY POINTS

- Lasers can effectively treat a wide range of congenital and acquired vascular lesions.
- Correct diagnosis is needed to decide when laser surgery is indicated and to select appropriate equipment and parameters.
- Safety and effectiveness of vascular lesion laser treatment is maximized when treatment adheres to the principles of selective photothermolysis, delivering sufficient energy at a wavelength that is well absorbed by the target, within a time period less than or equal to the target thermal relaxation time.
- Wavelengths targeting oxyhemoglobin or its derivatives are utilized for vascular lesion treatment.
- Shorter pulse durations (e.g. <3 ms) often produce purpura and are used to treat difficult to destroy port-wine stain (PWS) vessels; longer pulse durations (e.g., >6 ms) are often selected to treat erythema or telangiectases with minimal purpura for a more cosmetically acceptable treatment course.
- Epidermal cooling protects the epidermis, improving treatment safety, mitigating pain, and allowing treatment of dark skin types.

HISTORY AND SCIENCE

Background and history

Classification of vascular lesions

Treating vascular lesions is one of the most common and effective uses of laser surgery. Correct diagnosis is needed to decide when laser surgery is indicated and to select appropriate equipment and parameters. Most vascular lesions amenable to laser surgery can be classified into three categories (Table 11-1): malformations, benign tumors, and dilatations of pre-existing vessels.¹

Vascular malformations are present at birth and never spontaneously regress. They do not exhibit cellular proliferation but generally expand as patients grow and as vessels become more ectatic. Malformations are categorized according to predominant vessel type: venous, venular, capillary, lymphatic, arterial, or arteriovenous.^{2,3} Port-wine stains (PWS) are vascular malformations comprised of ectatic venules in the superficial dermis (Fig. 11-1). Normal cutaneous blood vessels range in diameter from 10 to 50 μm .⁴ In contrast, PWS vessel diameter ranges from 10 to 300 μm .^{5,6} As patients age, vessel number, mean vessel depth and vessel diameter increase slightly.⁷

Benign vascular tumors are associated with endothelial cell proliferation. Hemangiomas are the most common benign vascular tumor in pediatric patients. They may appear anywhere on the skin but affect the head and neck most commonly.⁸ Cutaneous hemangiomas may be superficial (capillary), deep (cavernous) or combined.⁸ Superficial hemangiomas usually

Table 11-1 Classification of vascular lesions

Category	Examples	Onset	Spontaneous involution
Malformations	Port-wine stains, venous, arterial, and lymphatic malformations	Always present at birth	Never
Benign tumors Dilatations	Hemangiomas Telangiectases, venous lakes, spider angiomas	At birth or first few weeks of life Variable; often arise in adulthood	Often Occasionally

**Fig. 11-1** Typical facial port wine stain.

exhibit a bright red color while deep lesions typically appear as subcutaneous nodules with normal or blue-tinted overlying skin.

These lesions may be present at birth or may arise within the first several weeks of life and are reported to occur in 2–3% of all neonates and in 10% of infants by 1 year of age.⁹ Most grow rapidly during an early proliferative phase which lasts until about 6 months of age and then spontaneously involute. The involution phase proceeds slowly with fibrous tissue replacing vascular parenchyma with maximal involution at 5 years of age in 50% and at 9 years of age in 90% of hemangiomas.⁹

Other examples of benign vascular tumors include cherry angiomas (Fig. 11-2), kaposiform hemangioendotheliomas, and glomus tumors.

Vascular dilatations are ectatic vessels with normal endothelial turnover. One of the most common examples is telangiectases which are permanent dilatations of end vessels, primarily venules. Telangiectases are associated with numerous conditions including rosacea, collagen vascular diseases, and cutaneous mastocytosis, or may occur as a result of trauma,

**Fig. 11-2** Multiple cherry angiomas on the trunk of a 45-year-old man.

radiation therapy, sun damage, endocrine factors, or high venous pressure. Venous lakes, spider angiomas, angiokeratomas, and lymphangiectases are other examples of vascular dilatations.

Early therapeutic lasers

The concept of light amplification by stimulated emission of radiation (LASER) was developed by Albert Einstein nearly a century ago.¹⁰ In the 1960s, dermatologist Leon Goldman first applied lasers for treatment of cutaneous lesions. In the 1970s, a commercially available argon laser allowed reliable treatment of cutaneous vascular lesions. These early lasers were associated with frequent adverse effects as the result of non-specific damage.^{11,12} Several factors contributed to these early adverse effects. First, there is significant melanin absorption at the short blue-green wavelengths (488, 514 nm) utilized for the argon laser. As light passes through the epidermis to targeted dermal PWS blood vessels, it must pass through melanin in the epidermal basal layer. Absorption of light by melanin can result in excessive epidermal heating and subsequent injury, including scarring and dyspigmentation. Second, early argon laser devices had relatively long pulse durations (0.5 s), which resulted in excessive perivascular heating and collagen damage.

Science

The theory of selective photothermolysis

As our understanding of how lasers interact with the skin has become more sophisticated, laser surgery has become more effective and safe. In 1983, Anderson and Parrish published the theory of selective photothermolysis, which described how a laser could be used to induce selective injury to a skin structure,

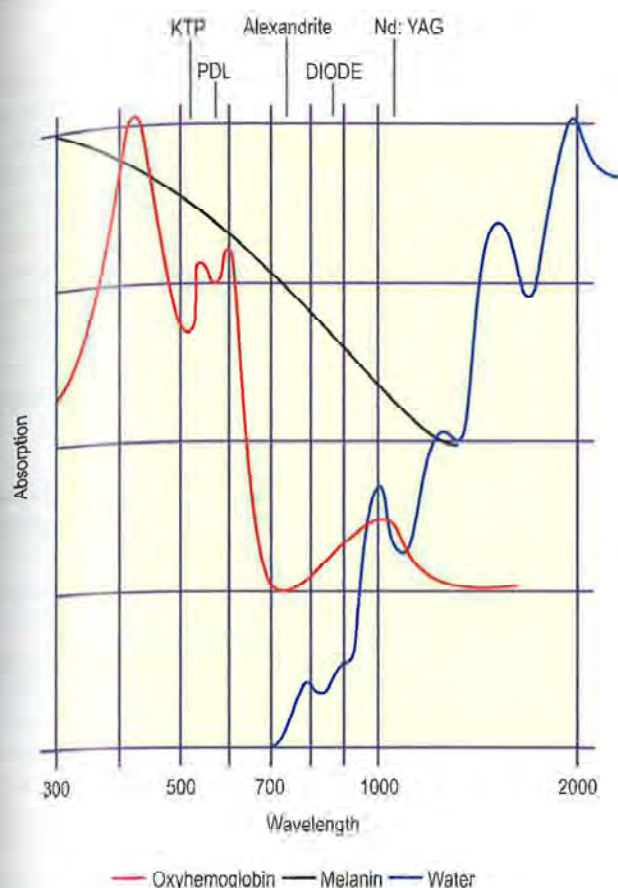


Fig. 11-3 Absorption spectra of common cutaneous chromophores. KTP (potassium titanyl phosphate); PDL (pulsed dye laser); Nd:YAG (neodymium:yttrium-aluminum-garnet).

whilst minimizing damage to surrounding normal tissue.¹³ According to their theory, treatment efficacy could be maximized and scarring minimized through assiduous attention to three parameters: wavelength, pulse duration, and fluence.

Wavelength

Injury of a cutaneous lesion can be achieved when a colored target (chromophore) absorbs light radiation and this energy is converted to heat. For selective injury, the wavelength utilized should be preferentially absorbed by the targeted chromophore and minimally absorbed by non-targeted chromophores. In the case of vascular lesions, oxyhemoglobin (HbO_2), deoxyhemoglobin and, in some instances, methemoglobin are the chromophore targets (Fig. 11-3). Each of these absorbs light over a range of wavelengths and has more than one absorption peak (e.g. HbO_2 absorbs at 418, 542, and 577 nm).¹³ Vascular targeting lasers have a wavelength at or near one of the HbO_2 absorption peaks. Since melanin absorption steadily decreases over this range, peaks at longer wavelengths are generally utilized to minimize epidermal melanin absorption (see Fig. 11-3).

Wavelength also determines depth of penetration (Fig. 11-4). Generally, longer wavelengths scatter less and therefore penetrate deeper into the skin (up to 1200 nm, above which the energy is preferentially absorbed superficially by water).¹³ To

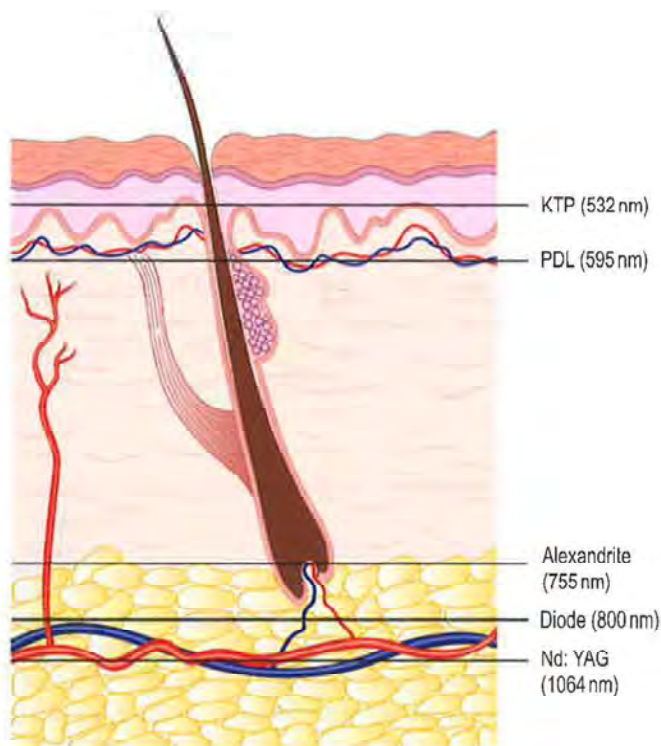


Fig. 11-4 Relative depth of penetration of select lasers used to treat vascular lesions. KTP (potassium titanyl phosphate); PDL (pulsed dye laser); Nd:YAG (neodymium:yttrium-aluminum-garnet).

treat vascular lesions, laser light must penetrate at least into the papillary dermis and preferably through the deep dermis to reach targeted vessels. Although a laser that emits at 418 nm would have the strongest and most efficient oxyhemoglobin absorption, it would not penetrate through the epidermis and therefore would be ineffective at treating dermal vascular anomalies. As such, most lasers that are used to treat vascular lesions use wavelengths of at least 532 nm; wavelengths in the near infrared (up to 1064 nm) can be used to treat deeper vessels. Sometimes it is necessary to use lasers of different wavelengths over several treatments to treat both superficial and deep aspects of a single vascular lesion.

Pulse duration

Laser pulse duration (also called the pulse width) should approximate the thermal relaxation time of the targeted vessel to minimize heat diffusion and concomitant damage to surrounding tissue. The thermal relaxation time is the time required for the target to cool to 50% of the maximum temperature induced by the laser.¹³ Thermal relaxation time is related to the size of the vessel, being proportional to the square of its diameter. Pulse durations significantly shorter than the thermal relaxation time of a vessel might not achieve adequate heating of the vessel wall, resulting in insufficient photocoagulation. High energies delivered over short pulse durations also often result in vessel rupture and extravasation of red blood cells (i.e. purpura). Pulse durations significantly longer than the thermal relaxation time result in heat

diffusion from the target to the surrounding tissue which can result in scarring or permanent dyspigmentation. Loss of energy to the surrounding tissue may also result in insufficient photocoagulation of the target vessel.

As an example, blood vessels within a PWS range from 10 to 300 μm in diameter.¹⁴ Thermal relaxation time for these vessels ranges from 1 to 10 ms.^{13,15} Shorter pulse durations (e.g. <3 ms) usually produce purpura and are used to treat difficult to destroy PWS vessels. Longer pulse durations (e.g. >6 ms) with higher energies are often selected to treat erythema or telangiectases with minimal purpura for a more cosmetically acceptable treatment course.

Fluence

Fluence (i.e. laser energy measured as watts $\times$ seconds/ cm^2) must be sufficient to damage targeted blood vessels. Irreversible vessel destruction occurs when blood is heated to approximately 70°C.¹³ Too much energy, even when delivered at the desired wavelength and pulse duration, may produce residual heat, injuring surrounding structures. Too little energy will not achieve desired vessel destruction.

In summary, the theory of selective photothermolysis described how selective thermal damage to a target can be achieved if sufficient energy is delivered at a wavelength that is well absorbed by the target and that is within a time period less than or equal to the thermal relaxation time of the target.¹³ This theory forms the central basis for laser parameter selection for treatment of vascular lesions and other chromophore targets in the skin. However, there are additional considerations.

Spot size

Spot size is the diameter of the laser beam. Fluence is related to spot size, being inversely proportional to the square of the radius of the spot size. Spot size also affects the depth of laser light penetration. With larger spot sizes, the beam is scattered less and light penetrates deeper. As a result, the ratio of dermal to epidermal damage is increased as spot size increases. Smaller spot sizes require relatively higher fluences to achieve the desired effect in the dermis and these higher fluences inflict greater epidermal damage. Therefore, using larger spot sizes increases effectiveness at equal fluences and increases safety.

Epidermal cooling

Selective photothermolysis improved laser treatment outcome, but significant issues remained. One of the most important was competition for absorption of laser light by epidermal melanin (see Fig. 11-3). Light absorption by epidermal melanin increases treatment pain and may result in epidermal injury manifested as blistering, hyperpigmentation, hypopigmentation, and scarring. In the 1990s, sophisticated epidermal cooling methods became widely available, decreasing treatment pain, permitting safe use of higher fluences, and allowing treatment of patients with darker skin types. Three methods of epidermal cooling are commonly utilized: contact (conductive) cooling, evaporative (cryogen spray) cooling, and convective or air cooling (Table 11-2).

In contact cooling, a cold object is directly applied to the skin surface, and the laser pulse is delivered through the cooling medium. This method provides cooling before, during, and after the laser pulse. Ice or refrigerated aqueous gels are simple methods which provide some degree of contact cooling and act as a heat sink. However, they warm rapidly and are messy. More sophisticated methods utilize a glass or sapphire window through which chilled water (about 4°C) circulates in a closed loop with an electrostatic chiller. Sapphire's high thermal conductivity provides more rapid surface heat extraction than glass. Contact cooling methods also provide improved index matching, optimizing laser light entry into the skin and reducing backscatter.¹⁶ Contact cooling may, however, cause inadvertent cooling of targeted blood vessels if application is prolonged. This may be especially problematic during treatment of small superficial vessels, for example, those in PWS.

In evaporative cooling (also known as cryogen spray cooling), a millisecond pulse of cryogen is sprayed onto the skin. Evaporative cooling is intrinsically more efficient than conductive cooling, creating larger gradients between the epidermis and dermis and minimizing inadvertent cooling of dermal targets.^{16,17} Commercially, the most commonly utilized cryogen is 1, 1, 1,2-tetrafluoroethane, which is a nontoxic, nonflammable Freon substitute (boiling point: -26.2°C). The duration of the cryogen spurt (10–100 ms) and the time delay between the spurt and the laser pulse (10–100 ms) is programmed by the operator. For PWS treatment, it has been shown that cryogen

Table 11-2 Active epidermal cooling methods

	Advantages	Disadvantages
Contact (conductive) cooling: Chilled glass or sapphire plate	Cooling before, during, and after laser pulse; Provides index matching	Higher risk of dermal cooling
Evaporative cooling: Cryogen spray cooling	Intrinsically efficient cooling with large temperature gradients; Low risk of dermal cooling	Cryogen cost
Convective cooling: Chilled air	No interference with laser light; No disposable costs	Air is a poor thermal conductor; Bulky cooling devices

spray cooling permits safe use of higher fluences, leading to improved clearance.¹⁸ One disadvantage of evaporative cooling is the cost of the disposable cryogen.

Convective cooling utilizes a continuous flow of chilled air directed at the skin during treatment. Different rates of airflow may be selected. Studies have shown that chilled air is an effective epidermal protection method but has a relatively poor thermal capacity and is inferior to a chilled sapphire window.¹⁹ Cold air has been demonstrated to reduce pain during 585 nm pulsed dye laser treatment of telangiectases.^{20,21}

Clinical studies: vascular lesion lasers

Over the last 45 years a wide range of lasers and light sources have been utilized for treatment of vascular lesions (Table 11-3). Current therapy most commonly relies on pulsed lasers which provide greater adherence to the concept of selective photothermolysis and improved treatment response with a low incidence of scarring and dyspigmentation.

Pulsed dye lasers

The flashlamp-pumped pulsed dye laser (PDL) has a long history of safe and effective use for treatment of vascular lesions and is frequently used as a reference for comparison in discussions of vascular lesion treatment.

PDLs produce yellow light by using a flashlamp to pump rhodamine dye as the active medium. They have proven to be both effective and safe in treating cutaneous vascular lesions with atrophic scarring in less than 0.1% of patients.²² Original PDLs were designed with a wavelength of 577 nm and pulse width less than 1 ms in accordance with the principle of selective photothermolysis.¹³ These lasers achieved good results for PWS treatment with minimal risk of scarring.^{23,24} However, it was subsequently discovered that wavelengths in the 585–600 nm range penetrated deeper without sacrificing vascular selectivity, improving efficacy.²⁵

Whereas the traditional 585 nm PDL had a pulse width of 450 μ s, newer 585 and 595 nm PDLs deliver pulse widths of 1.5–40 ms, allowing treatment of vessels with variable diameter. Longer pulse durations can be achieved by grouping trains of shorter pulses, and can achieve vascular injury without vessel wall rupture. Longer pulse duration significantly reduces post-treatment purpura and is generally favored by patients undergoing cosmetic procedures.

The PDL utilizes a fiberoptic cable to deliver round spots between 3 and 12 mm in diameter or 2 $\times$ 7 mm or 3 $\times$ 10 mm elliptical spots designed to treat individual blood vessels. Epidermal cooling is available on most devices and, as discussed previously, increases the threshold for epidermal damage and decreases patient discomfort during treatment. As a result, higher fluences can be used with excellent clinical response and minimal risk to the epidermis.^{26,27}

The PDL is considered the treatment of choice for most PWS and some hemangiomas. It is also an excellent treatment modality for facial telangiectases, poikiloderma of Civatte,

spider angiomas, cherry angiomas, and some leg veins, as well as a variety of nonvascular conditions.

Q-switched 532 nm potassium titanyl phosphate (KTP) lasers

When light from the neodymium:yttrium-aluminum-garnet (Nd:YAG) laser is passed through a frequency-doubling potassium titanyl phosphate (KTP) crystal, the wavelength is halved to 532 nm (green light), which is near the 542 nm absorption peak of oxyhemoglobin. In the Q-switched mode, the 532 nm Nd:YAG laser delivers pulses of 5–15 ns at high peak powers. Although this pulse duration is far shorter than the thermal relaxation time of blood vessels, it has been shown that the Q-switched 532 nm Nd:YAG laser can effectively treat small vascular lesions. Unlike the PDL, which causes intravascular coagulation of erythrocytes, the Q-switched 532 nm Nd:YAG laser causes acute rupture of the vessel wall. In a study of 10 patients with telangiectases or angiomas treated at a fluence of 3–4 J/cm², excellent results were seen in 70%, good results in 20%, and fair results in 10%.²⁸ Results were not as good when lower fluences (1–2 J/cm²) were used. While post-treatment purpura was rarely observed at lower fluences, moderate purpura was seen immediately after treatment in all patients treated at higher energies, followed by hyperpigmentation in 20% of subjects at 30 days and 10% at 60 days follow-up.

Millisecond-pulsed 532 nm KTP lasers

Pulsed 532 nm lasers deliver pulse widths of 1–50 ms, either by grouping trains of Q-switched pulses or delivering true millisecond pulses. Millisecond domain pulses approximate the thermal relaxation time of small cutaneous vessels such as telangiectasia. A distinct advantage of longer pulse widths is slower heating of blood vessels, reducing mechanical stresses on the vessel wall, and causing coagulation of vessels without rupture or purpura.^{29,30} The combination of selective absorption by oxyhemoglobin and pulse widths in the millisecond range makes these lasers ideally suited for treatment of superficial telangiectases, particularly those located on the face.^{31,32} Chowdhury et al. demonstrated that the 532 nm also has utility in treating PDL-resistant PWS, with 70% of patients having at least 25% blanching.³³

The pulsed 532 nm laser has several disadvantages. Its short wavelength does not penetrate deeply (see Fig. 11-4) thereby limiting its application to superficial vessels. Furthermore, the 532 nm wavelength has strong absorption by melanin, which raises the risk of epidermal damage in patients with darker skin. Adjuvant epidermal cooling can be used to address this issue to some extent.

Alexandrite lasers

Millisecond-pulse alexandrite lasers emitting at a 755 nm (near infrared) wavelength have achieved widespread use in laser hair removal. Based on a small hemoglobin absorption peak in the near-infrared range, alexandrite lasers have also

Table 11-3 Some lasers and pulsed light devices available for vascular lesion treatment

Device type product name (supplier)	Wavelength (nm)	Pulse duration	Comments
Pulsed dye lasers			
V-beam (Candela)	595	0.45–40 ms	Cryogen spray cooling
C-beam (Candela)	585	0.45 ms	Cryogen spray cooling
V Star (Cynosure)	585, 595	0.5–40 ms	Air cooling
Potassium titanyl phosphate (KTP) lasers			
UltraLight 532 (Adept Medical Concepts)	532	0.3–1.5 ms	Compact, portable
Aura i/Gemini (Laserscope)	532	1–50 ms	Contact cooling; 10 mm spot
Alexandrite lasers			
UltraWave (Adept Medical Concepts)	755	5–50 ms	
GentleLASE (Candela)	755	3 ms	Cryogen spray cooling
Diode lasers			
LightSheer XC (Lumenis)	800	5–400 ms	Sapphire contact cooling
Varilite (IRIDEX)	940	5–100 ms	
MedilasD (Dornier MedTech)	940	10–1000+ ms	Contact cooling available
Nedodymium:yttrium-aluminum-garnet (Nd:YAG) lasers			
UltraWave (Adept Medical Concepts)	1064	5–100 ms	
Gentle:YAG (Candela)	1064	0.25–300 ms	Cryogen spray cooling
VARIA (CoolTouch)	1064	0.3–500 ms	Cryogen spray cooling
CoolGlide Vantage (Cutera)	1064	0.1–300 ms	Contact cooling
Acclaim 7000 (Cynosure)	1064	0.4–300 ms	Cold air cooling
Fidelis (Fotona)	1064	5–50 ms	Cryogen spray cooling
FriendlyLight (FriendlyLight)	1064	0.5–1.5 ms	Portable
Lyra i/Gemini (Laserscope)	1064	20–100 ms	Contact cooling
Lumenis One (Lumenis)	1064	2–20 ms	Contact cooling
Profile 1064 (Sciton)	1064	0.1–200 ms	Contact cooling
Combined wavelength lasers			
Dualis VP (Fotona)	532 / 1064	5–200 ms	Cryogen spray cooling; 2 wavelengths fire simultaneously
Cynergy (Cynosure)	595 / 1064	0.5–40 / 0.3–300 ms	Air cooling; 2 wavelengths fire consecutively
Intense pulsed light devices			
Med-Flash (Alderm)	590–1000	0–40 ms	
Harmony (Alma Lasers)	540–950	10, 12, 15 ms	Spot 40 × 16 mm
Omnilight (American Medical Biocare)	480–1200	2500 ms	Spot 10 × 20 mm / 30 × 30 mm / 20 × 50 mm
Ellipse I ² PL (Candela)	400–950	1.5–100 ms	Spot 10 × 48 mm
Solera Opus (Cutera)	500–635	Variable	

Table 11-3 Some lasers and pulsed light devices available for vascular lesion treatment—cont'd

Device type product name (supplier)	Wavelength (nm)	Pulse duration	Comments
Intense pulsed light devices—cont'd			
Cynergy PL (Cynosure)	569–950	5–50 ms	Spot 46 × 18 mm / 46 × 10 mm / 21 × 10 mm
Quadra Q4	500–1200	10–110 ms	
Lumenis One PDL (Lumenis)	515–1200	3–100 ms	Contact cooling
Solarus (Novallis)	520–1200	20, 40, 60 ms	
MediLux/Starlux System (Palomar)	470–1400	10–100 ms	Contact cooling; photon recycling
Prolite II (Quantel Medical)	530–1200	20–72 ms	Spot 20 × 10 mm
Profile (Sciton)	400–1400	Up to 200 ms	Spot 15 × 30 mm; contact cooling

been utilized to target moderately deep, larger-caliber spider and feeding reticular veins, thick port-wine stains, and hemangiomas. An advantage of the 755 nm wavelength is deeper penetration of light as well as absorption by deoxygenated hemoglobin. One study demonstrated significant improvement in bulky PWS using the 755 nm alexandrite laser.³⁴ Other studies have shown that medium- and large-diameter leg veins (0.4–3 mm diameter) respond well, while smaller diameter vessels (0.4 mm diameter) respond less impressively to these devices.^{35,36} Given the higher energy needed to treat vascular lesions with alexandrite lasers as compared to PDL and KTP devices, treatment is significantly more painful.

Diode lasers

High-powered diode lasers emitting from 800 to 980 nm (near infrared) have also been used to treat vascular lesions. The 800 nm wavelength is moderately absorbed by hemoglobin, and penetrates relatively deeply into the dermis. Some reports have shown encouraging results in the treatment of medium-sized leg veins (0.4–1 mm diameter).^{37,38}

The 940 nm diode laser penetrates even deeper and has increased hemoglobin absorption as compared to 800 nm. The device has been shown to be effective in the treatment of leg veins and facial telangiectases resistant to therapy with a 532 nm PDL.³⁹

Both the 810 and 940 nm lasers can be introduced percutaneously into leg veins via an optical fiber and used intravascularly to treat leg veins. This will be further addressed in other chapters.

Nd:YAG lasers

The 1064 nm Nd:YAG laser can deliver high-powered, millisecond pulses to treat vascular lesions. Some systems allow delivery of multiple synchronized sequential pulses. Incomplete absorption at 1064 nm by hemoglobin allows for penetration of laser light into the entire vessel, including the posterior wall. However, lower absorption of the 1064 nm wavelength

by oxyhemoglobin requires use of significantly higher energies to achieve desired effects. The 1064 nm wavelength is poorly absorbed by melanin, which reduces the risk of epidermal injury in patients with darker skin types.

Pulsed Nd:YAG lasers are potentially useful for treating larger, deeper vessels such as reticular leg veins. Complete clearance of facial reticular veins has been reported in eight patients treated with a 1064 nm Nd:YAG in combination with epidermal cooling.⁴⁰ In an evaluation of treatment of leg vessels with a diameter of 0.5–3 mm diameter (50 sites treated on 30 patients), most improved by 75% 12 weeks after a single treatment.⁴¹ While immediate epidermal injury was not observed, post-treatment hyperpigmentation developed in 42% of patients, which resolved in 83% at the 3-month follow-up.

Multiple wavelength lasers

Laser irradiation of blood results in the transient formation of methemoglobin from oxyhemoglobin and clot. Methemoglobin and clot are not present in normal tissue and absorbs near-infrared radiation much more strongly than does oxyhemoglobin. Systems have been developed to capitalize on methemoglobin formation. A dual-wavelength Nd:YAG/KTP laser that emits simultaneously at 1064 and 532 nm has been shown to effectively treat PWS at a significantly reduced fluence than the 532 nm laser alone with no loss of efficacy.⁴² It has been proposed that to maximize on the effects achieved as a result of the formation of methemoglobin and clot, it may be advantageous to delay the second Nd:YAG pulse. The Cynergy (Cynosure, Westford, MA) is a two-laser device which has a 595 nm pulsed dye laser and a 1064 nm Nd:YAG laser that are fired sequentially. Preliminary reports have shown that this combined wavelength laser provides greater depth of treatment and significant improvement in recalcitrant vessels with lower fluences. In a study evaluating treatment of facial and leg telangiectases, Tanghetti et al. showed >75% improvement in 73% of lesions and noted that blebbed port-wine stains (frequently difficult to treat) had impressive response.⁴³

Intense pulsed light (IPL) sources

Intense pulsed light sources (IPLs) are intense, non-laser flashlamp devices that produce incoherent, multiwavelength light from 515 to 1200 nm (visible to infrared light). A series of filters is used to cut off the output below a predetermined wavelength, depending on patient skin type and lesion depth. Light is delivered through a large rectangular handpiece. Millisecond pulses are produced via a sequence of single, double, or triple pulses separated by a variable delay. A thin layer of cold aqueous gel is applied to the skin to protect the epidermis and improve light coupling to the skin. In addition, an attachable cooling bracket or built-in contact cooling can be used for added epidermal protection.⁴⁴

IPLs have been used to successfully treat a variety of vascular lesions, including PWS,⁴⁵⁻⁴⁷ hemangiomas, venous malformations,⁴⁸ poikiloderma of Civatte,⁴⁹ and telangiectases.^{49,50} In general, an increased number of sessions is required to clear vascular lesions compared with the PDL. The advantage of the IPL is its versatility given its wide range of wavelengths, pulse durations, and pulse sequences. In addition, its large spot size permits rapid treatment. Purpura is usually not produced; however, it may occur with use of high fluences or short pulse durations.

A disadvantage of IPLs is that they deliver some wavelengths that are preferentially absorbed by melanin. This may account for the increased incidence of adverse effects such as pigmentary change, blistering, and scarring in some reports.⁵¹ Further, IPLs produced by different manufacturers differ in spectral wavelength output and filter effectiveness, making it difficult to make generalized comments about these devices.

Clinical studies: laser treatment of specific vascular lesions

Port-wine stains

The pulsed dye laser is currently the treatment of choice for most PWS, especially those that are macular or only mildly hypertrophic (Fig. 11-5). Many studies have demonstrated the safety and efficacy of PDL in combination with epidermal cooling for PWS treatment.⁵²⁻⁶⁴ In one study of 76 patients with PWS, overall clinical improvement of 79% was achieved after an average of nine treatments.⁵⁵ Multiple treatments (25+) may be necessary to achieve maximum lightening of some lesions.⁶⁵ While most PWS can be lightened with the PDL, complete clearing is infrequent, occurring in fewer than 20% of cases,^{54,59,65} and some lesions are resistant, demonstrating limited response even after multiple treatments (Fig. 11-6). A recent study⁵³ evaluated efficacy of PWS therapy in patients referred to a tertiary care center. Fifteen percent of subjects achieved lightening of 75% or greater after an average of 4.3 treatments, 10% were evaluated to have lightening of 50-74%, 15% had lightening of 25-49%, and 60% had less than 25% lightening.

It is difficult to predict which PWS will respond most favorably to laser treatment. However, some studies have provided guidelines regarding lesion response. Garden et al. evaluated 52 patients and found that purple, nodular lesions were in many cases resistant to treatment.⁵² Poor response is likely due to large red blood cell content in very ectatic vessels which may shield deeper vessels from laser light. Deeper vessels may also be present that are beyond the effective penetration depth of the PDL.

**A****B**

Fig. 11-5 Facial PWS (A) before and (B) after treatment with the pulsed dye laser.

A group of studies report that young children require fewer treatments for clearance and achieve more lightening per treatment than older patients.⁵³⁻⁵⁷ Pediatric PWS may respond more favorably because of smaller vessel diameter, more superficial vessel location, smaller lesional size and perhaps even improved epidermal optics (thinner epidermis). However, pediatric PWS responsiveness remains controversial. One prospective study of 100 pediatric and adult patients found no significant difference in PWS lightening between age groups. No patient in this study achieved complete lesion clearance.⁵⁸

Anatomic location is another potential predictor of treatment response.^{59,60} PWS located on the face and neck often respond favorably as compared to trunk and extremity lesions.⁶¹ Centrifacial lesions (medial cheek, upper lip, and nose) generally respond less favorably than those on other facial areas. Lesions localized to dermatome V2 are often more resistant than PWS in V1, V3, and C2/C3 distributions. Lesions located on the upper and lower extremities generally respond poorly.^{59,61,62}

Lesional size may also help predict laser therapy response,^{63,64} with smaller lesions generally responding better. PWS vessel characteristics, including depth, number, and diameter, are also relevant.^{61,65} PWS with a reticulate pattern and superficial vessels appear to respond more favorably.⁶⁵ One study found that poor responders had significantly smaller (mean vessel diameter 19 μ m) and greater number of vessels as compared to moderate and good responders.⁶⁵

Absorption of laser energy by epidermal melanin inhibits light delivery to targeted PWS vessels making it more difficult to treat patients with darker skin types. Temporary or sometimes permanent pigmentary changes can occur in these patients.

We believe that in an ideal PWS treatment protocol, wavelength and pulse duration should be varied, in order to target vessels of different size and depth throughout the lesion. Some of this variation can be achieved with PDL devices that have varied wavelength (585–600nm) and pulse duration

(0.45–40ms). Resistant lesions may also benefit from use of alternative laser devices.

Dierickx and colleagues used a pulsed, 532nm laser to treat 11 patients with nonfacial, pink to purple PWS.⁶⁶ The laser was used with a computer-driven scanner that placed 127 spots of 1mm diameter in a hexagonal pattern. Pulse durations of 3, 5, 10, and 15ms were compared. The best results were obtained with 3 or 5ms pulse widths at a fluence of 15 or 20J/cm². Immediate clinical response was transient blanching without purpura, but delayed purpura occurred at all sites within several days. Other studies have shown >50% improvement in facial and neck PWS in 95% of patients treated with a 532nm laser at 9.5–20J/cm² and 15–20ms pulse width,⁶⁷ as well as lightening of previously treated, PDL-resistant PWS at 18–24J/cm² and pulse widths of 9–14ms.⁶⁸

IPLs have also been reported to effectively treat both untreated^{45,47} and treated but nonresponsive PWS.⁴⁶ In a retrospective study, 70–100% clearance was achieved in 28 of 40 PWS treated with an IPL device.⁴⁵ Although better results were seen with pink and red PWS, good clearance (70–99%) was achieved in 6 of 11 purple lesions. Treatment parameters were not standardized, but the most frequently used parameters were cut-off filters of 515 and 550nm, pulse durations of 2.5–5ms, and fluences of 24–60J/cm². Purpura developed in most patients, while crusting was seen in 20%, and superficial blistering in 8%. No scarring was observed in this study.

Yang et al.⁶⁹ treated PWS three times with a 1064nm Nd:YAG laser using a 5 or 7mm spot size, radiant exposures of 40–130J/cm² and pulse durations of 4–10ms. Performing treatments in conjunction with contact cooling and using non-overlapping pulses, the authors achieved good blanching results without adverse effects when energies were kept at or below the minimum purpura dose. Six percent had more than 75% clearing, 31% had 51–75% clearance, 25% had 26–50% clearance, and 38% had clearance of 25% or less. Scarring was noted in one patient who was treated at energies above

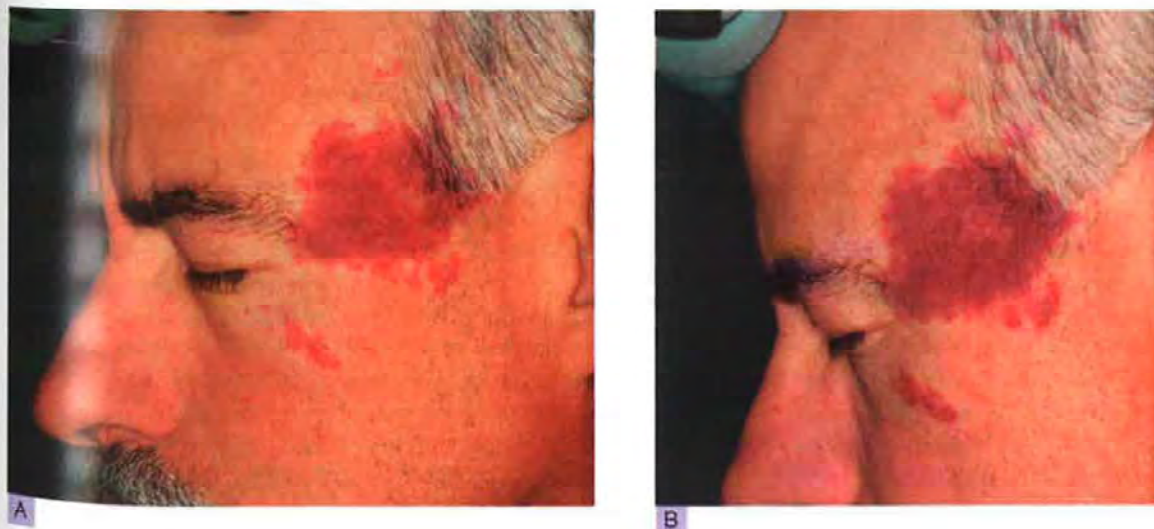


Fig. 11-6 Resistant PWS after four treatments with the pulsed dye laser.

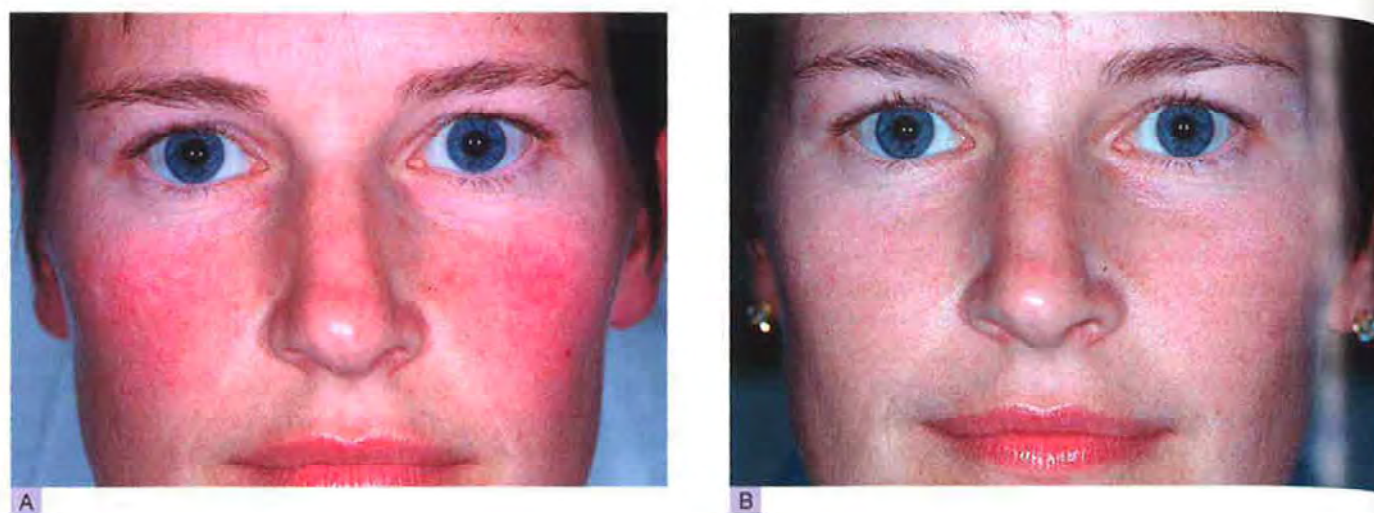


Fig. 11-7 Facial telangiectasia (A) before and (B) after one treatment with the 595 nm pulsed dye laser.

the minimum purpura dose. Histologic analysis of biopsies confirmed that deeper vessels could be treated with the Nd:YAG (>2 mm) as compared to the PDL (1 mm).

Facial telangiectases and other small vessel disorders

Selection of device and treatment parameters for telangiectases requires consideration of vessel diameter, anatomic location, patient age, and patient expectations regarding results and post-treatment healing.

Small-diameter vessels on the face usually respond favorably to any of the millisecond duration lasers previously discussed. The PDL represents an excellent treatment modality for facial telangiectases (Figs 11-7, 11-8), even more difficult to treat lesions such as those associated with collagen vascular disease or Osler-Weber-Rendu syndrome.⁷⁰ Spot sizes (up to 12 mm) allow confluent treatment of large areas. Alternatively, larger telangiectases may be treated individually along their length with an elliptical spot. The primary disadvantage of PDL use is the potential occurrence of purpura immediately after treatment, which may last up to 2 weeks. This is minimized or eliminated completely by use of longer pulsed durations (>6 ms). However, significantly longer pulse durations might also limit treatment response, thereby increasing the number of required treatment sessions.⁷¹ To improve response with use of longer pulse durations, multiple passes or judicious pulse stacking over the same area can be used.⁷²

Pulse stacking improves results by several different mechanisms. When a targeted vessel is hit with a laser pulse the intravascular temperature increases. If the same vessel is hit again with another laser pulse before the temperature has returned back to normal, another incremental increase in vascular temperature occurs. If this is done repeatedly with pulse stacking, the intravascular temperature continues to slowly increase and cause a greater thermal effect on the targeted endothelial cells

of the vessel wall and therefore a greater clinical response. By increasing the temperature slowly in this manner, there is only a minimal increased risk of purpura. There is, however, a greater risk of postoperative edema. Also, when a red blood cell is hit with a laser pulse and is heated, it undergoes a conformational change and its shape becomes elongated. As in sickle cell anemia, the elongated red blood cells (RBCs) do not flow as well through the blood vessel and tend to sludge in the area. This creates a greater mass of RBCs and therefore a more rich target for subsequent laser pulses. In addition, as oxyhemoglobin is hit with a laser pulse, it can be transformed into methemoglobin. Methemoglobin has greater absorption of both 532 and 595 nm light and therefore makes a better target with subsequent pulses. All of these factors lead to the greater response of stacked laser pulses in the treatment of vascular lesions. Rohrer et al. noted a 30% improvement when nonpurpuric stacked pulses were compared to nonpurpuric single pulses.⁷²

Facial telangiectases also respond favorably to millisecond-pulsed 532 nm green light lasers.³¹ Pulsed green light lasers coagulate small- and medium-diameter vessels with minimal or no purpura. The target vessel can be traced with a laser beam with a spot size that approximates the diameter of the vessel or the entire field may be treated with larger spot sizes (10 mm). Many of these devices use contact cooling for epidermal protection. It is imperative that good contact be maintained throughout treatment, especially in high-risk areas such as the ala and alar grooves; compromise of contact can result in depressed scars. One study found the 532 nm KTP to be more effective and less painful but have a higher incidence of edema than PDL treatment of telangiectases.⁷³

IPLs are another effective treatment modality for facial telangiectases. Purpura is minimal or absent and handpieces allows confluent treatment of large areas. However, more treatments may be required for desired results as compared to



Fig. 11-8 Large facial telangiectasia (A) before and (B) after two treatments with the 595 nm pulsed dye laser



Fig. 11-9 Angioma (A) before and (B) after one treatment with the 595 nm pulsed dye laser.

laser devices. In a small study, Raulin and colleagues reported good to excellent clearing of telangiectases (mostly facial) after an average of 4.4 treatments.⁴⁹ Clementoni and colleagues reported 88% of patients had >75% clearance of facial telangiectases after an average of 1.69 treatments.⁷⁴

Spider and cherry angiomas typically respond after one or two treatments with the PDL (Fig. 11-9).⁷⁵ One pulse with the 3 or 5 mm spot size usually treats the entire lesion. Pulsed 532 nm lasers are also effective, but higher fluences may be

necessary. For spider angiomas, treatment of the central feeding vessel followed by irradiation of the peripheral vessels achieves the best results. Spider and cherry angiomas may also respond to IPL; however, their large spot size makes treating small superficial targets more difficult. In children, the use of a PDL is preferable for telangiectases or spider angiomas given the high therapeutic safety index.

Large blue vessels often present in the periorbital area. Due to their size and depth, these vessels do not respond well to

the PDL. They may be effectively treated with long-pulsed infrared devices such as the long-pulsed alexandrite laser or long-pulsed Nd:YAG lasers. Care must be taken when long-pulsed lasers are used in the periorbital region as eye injuries have occurred even when proper eye protection was used.⁷⁶ As such, these vessels are best treated by someone with appropriate experience and knowledge of laser-tissue interactions.

Hemangiomas

Treatment of hemangiomas has long been a source of controversy. Because of the natural history of these lesions and the potential for involution, many lesions do not need to be treated. Treatment may be indicated if the hemangioma is rapidly proliferating, ulcerating, or is affecting important structures such as the eyes or mouth. Treatment may also be indicated for hemangiomas on the nose, lip, or ear because they are more likely to heal with scarring or with permanent anatomic distortion.⁷⁷

The PDL has been the treatment of choice for superficial hemangiomas selected for laser therapy.^{78,79} Use of a PDL with longer wavelength (595 nm) and pulse duration (1.5 ms or longer) may be more effective due to a greater depth of penetration. Typically, the laser produces lightening and flattening of hemangiomas as well as a slowing of proliferation and improvement in ulceration. Multiple

treatment sessions are usually required to achieve the maximum benefit; treatment of lesions that are rapidly proliferating should be repeated at 2–3-week intervals, and those that are not rapidly proliferating should be repeated at 4–6-week intervals. Because of limited penetration depth (about 1.2 mm),²⁵ PDL is not useful for lesions with only a deep component.⁷⁸ Further, PDL treatment may have limited effect for proliferating hemangiomas that have acquired significant thickness or depth. Whereas lesions that are raised 3 mm or less off the skin surface often achieve significant response, those raised more than 4 mm may lighten with therapy, but show less diminution in thickness.⁸⁰

Thicker hemangiomas are often better treated with longer wavelength lasers such as the 755 nm alexandrite or 1064 nm Nd:YAG lasers. The longer wavelengths of these lasers will penetrate more deeply into these thick lesions and have a greater clinical response (Fig. 11-10).

Once hemangiomas are in the involutional phase, the PDL can be used to hasten resolution of the superficial component.⁸¹ Although these lesions are in a stage of regression, they are often slow to resolve and may persist beyond school age, prompting a desire by the patient or parents for treatment. The response to therapy is often rapid (within two to four sessions), and lesions may be treated every 6–8 weeks.



Fig. 11-10 Hemangioma (A) before and (B) after two treatments with a long-pulsed 755 nm alexandrite laser.

PROCEDURES AND TECHNIQUES

Preoperative clinical considerations

Anesthesia

Most patients experience a well-tolerated, transient stinging sensation during laser or IPL vascular lesion treatment. As such, for most patients, anesthesia is not required. For sensitive patients, a thick layer of a topical lidocaine preparation under occlusion for 60 minutes is generally adequate anesthesia. Alternatively, local infiltration or a regional nerve block with lidocaine can be used. Epinephrine should be avoided, as it will constrict vessels, diminishing the target and limiting efficacy. The exception is for nerve blocks where epinephrine significantly potentiates block effectiveness. Premedication with hypnotics, sedatives, or analgesics are generally not required, but may be helpful for anxious patients.

General anesthesia should be considered for treatment of lesions in infants and children that require multiple pulses. While use of general anesthesia is somewhat controversial, we feel it is preferable, especially since children with vascular birthmarks often require many treatments. In addition, protective eyewear is required during laser therapy (see below) and may frighten conscious children. Finally, it is safer to use the laser with the child immobilized under anesthesia. Frequently, the anesthesiologist uses a laryngeal mask airway or mask inhalation with sevoflurane as the anesthetic. Older, more mature children may undergo intravenous induction. General anesthesia for pediatric patients for these brief procedures is generally safe; one study reported no serious adverse events in 881 procedures performed.⁸²

Laser safety

Appropriate, wavelength specific safety goggles must be worn by all personnel in the treatment room. Patients must also wear protective eyewear appropriate for the procedure. For treatment of nonfacial areas, patients may wear the same goggles worn by assisting personnel, provided they are the type that have complete contact with the skin and seal the entire periocular region off from reflected laser light. If the face but not the periorbital area is treated, then folded gauze with overlying metal goggles can be used. Corneal shields inserted with the aid of ocular anesthetic drops are required for treatment of the periorbital area, including the eyelid. Confirmation of adequate size and correct placement of eyewear is crucial. Several cases of eye injury have been reported when long-pulsed, longer-wavelength lasers were used within the bony orbit, even though eye protection was utilized. As such, use of these devices in the periorbital area should be avoided or approached with extreme caution by someone trained in such procedures.

Although extremely rare, lasers have been reported to cause flash fires.⁸³ To minimize this risk, makeup should be removed prior to treatment, and if alcohol is used to clean the skin or laser handpiece, it must be allowed to dry completely before treatment. Whenever possible, lasers should be used with room air only. If oxygen use is required, then a closed airway system should be used to avoid oxygen leakage. Water and a fire extinguisher should be immediately available.

Device-specific procedural techniques

Pulsed dye laser



- Use largest spot size possible to insure maximal light penetration into tissue.
- PDLs should always be used with epidermal cooling during treatment of vascular lesions.
- The laser handpiece should be held perpendicular to the skin, with the attached spacer resting on the skin.
- Best results are achieved when pulses are overlapped slightly.
- Purpura is required for PWS treatment but can be avoided during treatment of facial telangiectases by using longer pulse durations (>6 ms).
- Judicious pulse stacking and multiple passes optimize results when using long pulse durations.
- Wavelength and pulse duration should be varied in the course of PWS treatment to target vessels of varying diameter and depth.



- Failure to overlap may result in a checkerboard pattern of lesion resolution.

Port-wine stains

Test areas For practitioners with limited experience, it may be useful to perform test areas prior to treatment of an entire PWS, in order to determine optimal fluence and prepare the patient for the postoperative course, especially the purpura (Fig. 11-11). An area should be chosen that is representative of the entire lesion. Several test spots may be performed using different fluences to determine the best therapeutic response. Purpura should be produced, as subpurpuric doses are less effective.⁸⁴



Fig. 11-11 Purpura 1 hour after pulsed dye laser treatment (short pulse duration) of a facial port-wine stain.

Test areas should be evaluated in 4–6 weeks for degree of lightening as well as for undesired textural or pigmentary sequelae. If noticeable lightening has occurred without adverse effects, then treatment can proceed using the fluence that produced the best results. Absence of lightening indicates that higher fluences, alternative pulse widths, or different wavelengths should be considered.

Treatment It may be helpful to treat facial PWS with the patient in the Trendelenburg position to increase blood flow to the PWS and presumably increase the chromophore target. Treatment of infants and young children is generally initiated at $5\text{--}8\text{J}/\text{cm}^2$ (depending on Fitzpatrick skin type) and increased by $0.5\text{--}1.0\text{J}/\text{cm}^2$ with each treatment, if no adverse effects are noted. Lower radiant exposures are used for the eyelid, neck, and upper lip because these areas are more prone to scarring. Beam profiles differ among available PDLs and, thus, different fluences may be required to achieve equivalent tissue responses.⁸⁵ We commonly utilize shorter pulse durations (0.45–3 ms) with a spot size of about 7 or 10 mm. Larger spot sizes offer more uniform energy transmission, deeper penetration, and rapid treatment and, thus, the largest spot size which will permit the desired radiant exposure should be chosen. PDLs should always be used with epidermal cooling during treatment of vascular lesions. Cryogen spray cooling parameters are in the range of 30–50 ms spurt duration with a 20–30 ms delay between the end of the spurt and laser pulse onset.

During treatment, the handpiece is moved across the PWS in a methodical fashion. The laser handpiece should be held

perpendicular to the skin, with the attached spacer resting on the skin. Best results are achieved when pulses are overlapped by 10–20%, avoiding the checkerboard pattern of lightening seen when spaces are left between pulses. Skipped areas can be filled in at the end of the treatment. During treatment, an erythematous flare often develops that obscures the margins of the PWS. To avoid this problem, one should treat the edges of the PWS first (the resulting purpura will outline the margins) or use a skin marking pen to delineate the border of the lesion prior to treatment.

We believe that in an ideal PWS treatment protocol, wavelength and pulse duration should be varied during treatment course, in order to target vessels of different size and depth throughout the lesion. Some of this variation can be achieved with different PDL devices. Physicians and patients must understand that multiple treatment sessions are required for PWS and complete removal can not be guaranteed.

Postoperative clinical considerations Post-treatment, patients experience local swelling, purpura (see Fig. 11-10) and pain which is similar to a sunburn sensation. Ice packs and elevation of the treated area for the first day after treatment will diminish swelling. Cooling soaks, mild analgesics such as acetaminophen, and the application of emollients (aloe vera gel or Aquaphor Healing Ointment—Beiersdorf Inc., Norwalk, CT) can be used to minimize discomfort. Mild crusting, which develops in approximately 20% of patients, should be treated twice a day with gentle washing and application of an ointment. Vesiculation and thick crusting is abnormal and may be a sign of infection. To minimize hyperpigmentation, avoid treating when the patient is tan. Patients should be instructed in good sun protective practices and can be prescribed bleaching creams (such as hydroquinone-containing agents) to be started once bruising has resolved. Treatments are repeated at 6–12 week intervals and multiple treatments (3–15 or more) are typically required.

If a patient wishes to conceal purpura or skin discoloration, makeup may be applied if crusting is not present. Makeup with a green base may be helpful; although most discoloration can be concealed completely only by using opaque makeup. When makeup is removed, the skin should not be wiped, and astringents or irritants should be avoided.

When PDL treatment of PWS is performed with appropriate fluences, correct technique and epidermal cooling, serious postoperative complications are rare. Cutaneous depressions or atrophic scarring, which have been reported in up to 4% of patients,^{86,87} may be due to excessive fluences, excessive spot overlap, trauma, or failure to use epidermal cooling. Hypertrophic scarring is distinctly uncommon but has been reported to occur on the face,⁸⁸ neck,⁸⁷ and chest,⁸⁹ and in patients taking isotretinoin.⁹⁰ In most cases, textural changes are transient and resolve spontaneously within 1 year. Transient hyperpigmentation, which occurs in about 25% of patients,^{86,91} is associated with sun exposure and darker skin types. Hypopigmentation is uncommon but risk is highest in patients with actinic bronzing and skin types III or higher.

Facial telangiectases and spider angiomas

Treatment Test areas are generally not necessary. Treatment technique is similar to that used for PWS treatment (including use of epidermal cooling), except that good results can be obtained without creation of purpura. Purpura can be avoided by use of longer pulsed durations (6–20 ms). Treatment end point is vessel disappearance or a darkening of the vessel. Judicious pulse stacking can be used to achieve the desired end point. Whitening or blistering of the skin are signs of epidermal damage and should be avoided.

The elliptical spot may be useful for treatment of linear telangiectases. When using the elliptical spot, the handpiece should be positioned at one end of the vessel and moved progressively along its length so that the entire vessel is treated with minimally overlapping pulses. The direction of treatment either in or against the direction of blood flow is unimportant. Reactive erythema often develops in the irradiated areas during treatment, making it difficult to see residual vessels. Patients should be informed that multiple treatments will be necessary for optimal results.

When treating spider angiomas, a spot size large enough to cover the entire lesion should be used when possible. The radiating 'legs' should be treated even if they appear to blanch after treatment of the central papule. Treatment may be performed through a glass slide compressed against the skin to target the deeper component. Care must be taken to avoid breaking the slide and the clinician must remember that the glass slide will hinder or block epidermal cooling and treatment parameters must be adjusted accordingly. If significant blood flow persists within the angioma after irradiation, it may be necessary to repeat treatment immediately, using higher fluence.

Postoperative clinical considerations

Postoperative care is similar to that described for PWS although again purpura may not be necessary for treatment results. Most telangiectases and spider angiomas respond very well to PDL treatment. Smaller telangiectases resolve almost completely after one treatment. Larger vessels and those located in the nasal folds may require several treatments.

Hemangiomas

Treatment. Anesthesia is usually not required, although use of topical, intralesional, or even general anesthesia may be useful during treatment of large lesions. Test spots can be considered but will delay full treatment by at least 2 weeks and some hemangiomas appear to respond only when they are treated in their entirety. Best results may be obtained using large spots size and lower fluences (for example, a 10 mm spot and 6 J/cm²) and once again, use of epidermal cooling is crucial.⁹² PDLs with longer wavelengths (595 nm) and pulse durations (1.5 ms or longer) may be optimal, especially for thicker lesions. Alternatively, longer wavelength lasers such as the 755 nm alexandrite or 1064 nm Nd:YAG may be used for even deeper penetration. Generally, two to six treatments are required for adequate clinical response. Treatments are usually repeated at 2–8-week intervals, with shorter intervals used for proliferating lesions.

Postoperative clinical considerations. Postoperative care is similar to that described for PWS and telangiectases. Ulcerative hemangiomas may respond to application of bio-occlusive dressings such as Duoderm (ConvaTEC, Princeton, NJ). When the appropriate technique is used, complications are not common, although ulceration and hypopigmentation have been reported.⁹³

Pulsed 532 nm Lasers



PEARLS

- The laser handpiece should be held perpendicular to the surface, with the handpiece spacer in good contact with the skin.
- Vessels should be traced at a speed that seals vessels without causing overlying epidermal injury.
- If vessels do not disappear, then the handpiece should be moved more slowly or the fluence can be slowly increased until vessel disappearance is achieved.
- If epidermal whitening is noted, then the fluence is too high, the vessel is being traced too slowly, or excessive overlapping is occurring.
- Avoid pulse stacking.
- Minimal pressure should be applied with the cooling tip so vessels remain patent and the target is not diminished.



PITFALLS

- Higher melanin absorption at the 532 nm wavelength increases potential for adverse effects in patients with darker skin types.
- Incomplete epidermal cooling and adverse effects can result if the cooling tip is not in good contact with the skin at all times.

Port-wine stains

Treatment Anesthesia considerations are the same as discussed above for PDL. Treatment may be accomplished via the freehand or scanning technique. For the freehand method, the largest laser beam spot size that delivers sufficient fluence should be used. The handpiece should be held perpendicularly to the skin surface, and the handpiece spacer should be placed on the skin. Magnification of at least 5–10 times is needed to visualize the individual vessels that make up PWS. The most effective devices for visualizing intradermal vessels are polarized magnified light sources (Syris Scientific, Gray, ME).

The vessels should be traced at a speed that seals the vessel without causing overlying epidermal injury. If the vessel does not disappear, then the handpiece should be moved more slowly or the fluence should be slowly increased until threshold fluence for vessel disappearance is reached. It may also be necessary on some systems to adjust the pulse width independently of the fluence. Optimal clearing of PWS has

been reported at a pulse width of 3 or 5 ms.⁶⁶ Larger-diameter vessels may require the use of longer pulse widths to achieve desired vessel coagulation.

If epidermal whitening is noted, then the fluence is too high, the vessel is being traced too slowly, cooling is inadequate, or excessive overlapping is occurring. Once the optimal fluence, pulse duration, and tracing speed have been determined, the rest of the vessels of that caliber, depth, and color can be treated with these parameters. Repeated tracing may be required to coagulate some vessels, especially large-caliber deep vessels. However, any one area should be treated only once with each pass.

The scanning technique is performed with a scanning device that is attached with fiberoptics to the laser. The scanning handpiece should be held perpendicular to the skin surface. The fluence should be slowly raised until the threshold fluence, defined as subtle blanching of the skin, is reached. The scanner should not be moved until the entire scanning pattern has been delivered. The handpiece should then be moved in a methodical fashion to an adjacent area, taking care not to overlap previously treated areas.

Postoperative clinical considerations Post-treatment discomfort can be lessened with the application of ice, cold tap water-soaked gauze or hydro-occlusive dressings (e.g. Vigilon, Bard Medical, Murray Hill, NJ). Postoperative edema can be significantly reduced with application of ice for the first 6 hours after treatment. Erythema usually subsides within 24 hours. Crusting may develop within 1–2 days and last for 7–14 days; it occurs more commonly when patients with darker skin phototypes are treated.

Purpura is much less common with pulsed 532 nm lasers as compared to PDLs, but mild purpura may develop with the use of high fluences and short pulse durations.

Patients should wash the treated area gently with a mild soap and water twice a day and then apply an occlusive ointment such as Aquaphor Healing Ointment (Beiersdorf Inc., Norwalk, CT). Post-treatment sun protection is important to minimize the risk of postinflammatory hyperpigmentation. Repeat treatments should be delayed by at least 6 weeks to allow maximal lightening and ensure complete healing, including fading of postinflammatory hyperpigmentation.

Facial telangiectases and spider angiomas

Treatment Anesthesia is usually not required. The spot size, pulse duration, and fluence are determined by vessel size and depth. The spot size should be slightly wider than the vessel diameter and the pulse duration slightly longer than the thermal relaxation time of the vessel. Alternatively, an entire area may be treated with a 10 mm spot size and then any residual vessels may be traced out. The laser handpiece should be held perpendicular to the surface, with the handpiece spacer in contact with the skin. Use of a polarized magnifying device improves visualization of dermal vessels.

Vessels should be traced at a speed just slow enough to cause scaling and vessel disappearance without producing epidermal damage such as whitening. Using too high a repetition rate increases the risk for double-pulsing sites, raising the risk of side effects such as epidermal necrosis and scarring. Particular caution should be used when treating the nasal ala and alar creases, as these sites are prone to atrophic scarring. If vessel disappearance does not occur during treatment, then the fluence and pulse duration should be increased incrementally, or the handpiece should be moved more slowly.

When using a laser with a cooling tip, the handpiece should be held perpendicular to the surface with the cooling tip flat and in direct contact with the skin. A thin layer of aqueous gel applied to the skin will facilitate moving the tip and prevent it from fogging up. Minimal pressure should be applied with the cooling tip so that vessels remain patent. If too much pressure is applied, then the vessel may be blanched, making treatment less effective.

When treating spider and cherry angiomas, the spot size should be selected to match the diameter of the target lesion. The technique used is similar to that for telangiectases. With spider angiomas the radiating vessels must also be treated. When large cherry angiomas or high-flow spider angiomas are treated, it may be necessary to use higher fluences that coagulate the epidermis to ensure sufficient thermal damage to the target vessels. The immediate end point of treatment is disappearance of the lesion or superficial whitening.

Postoperative clinical considerations Postoperative care is similar to that described for treatment of PWS. Reactive erythema that develops around the treated area usually fades within 24 hours. Crusting occurs rarely, but when present can last 3–14 days. Crusting is usually a sign of overly aggressive treatment, except in the case of deep or wide-caliber vessels that respond only to aggressive therapy.

Although facial telangiectases generally respond well to treatment, multiple treatment sessions may be required to achieve optimal clearing. Occasionally, recanalization and vessel reappearance occurs after treatment. Re-treatment may be safely performed 6 weeks after the original treatment if the treatment area is completely healed.

Intense pulsed light sources



- Patients with darker skin phototypes should be treated with a longer wavelength filter and a longer pulse delay.
- Single pulses should be used for small vessels, double pulses for medium vessels, and triple pulses for large vessels.
- Lower fluences (20% below those recommended by the manufacturer) should be used initially until the skin response has been observed.
- After the pulse is delivered, gel should be wiped off to observe the skin response.

- IPLs require operators to select a number of treatment parameters, including filter, pulse mode (single, double, or triple), pulse duration, pulse delay, and fluence.

Treatment

Intense pulsed light sources require operators to select a number of treatment parameters, including filter, pulse mode (single, double, or triple), pulse duration, pulse delay, and fluence. Software provides suggested treatment parameters based on lesion type, skin type, and predicted vessel depth, but parameters may be changed based on individual experience.

The cut-off filter should be chosen according to the patient's skin type and lesion depth. A shorter wavelength filter (e.g. 515 nm) should be used on type I skin only for superficial and smaller vessels. A longer wavelength filter (e.g. 570 nm) should be used for those deeper and larger vessels. Patients with darker skin phototypes should be treated with a longer wavelength filter and a longer pulse delay. Theoretically, use of a longer pulse delay allows the epidermis to cool between pulses, reducing the risk of epidermal injury. Single pulses should be used for small vessels, double pulses for medium vessels, and triple pulses for larger vessels. The theoretical advantage of multiple pulses is the ability to damage larger and deeper vessels through additive heating.⁴⁵ Pulse delays should be longer for larger vessels to allow uniform heating of the entire vessel. Conversely, pulse delays should be very short for small vessels.

Before commencing treatment, a layer of cooling gel should be applied on the area to be treated. If available, epidermal cooling should be utilized. The handpiece should be placed perpendicular to the skin surface. Lower fluences (20% below those recommended by the manufacturer) should be used initially until the skin response has been observed. After the pulse is delivered, the gel should be wiped off to allow inspection of the tissue response. If the targeted lesion appears unchanged and there are no epidermal changes, then the fluence may be increased and an adjacent area treated. If no response is observed, then the fluence can again be increased. If the desired tissue change is not seen, then the pulse width should be increased, leaving the fluence the same.

Postoperative clinical considerations

Reactive erythema may develop in the treated area but typically subsides within 24 hours. Postoperative care is similar to that described above for PDL and 532 nm lasers. Crusting is an uncommon occurrence and is seen mostly in patients with darker skin types or with the use of excessive fluence or short wavelength filter. Again, post-treatment sun protection is important.

Conclusion

Treating vascular lesions is one of the most common and effective uses of laser surgery. When currently available laser and light source devices are used properly, they can lighten or remove vascular lesions achieving significant patient satisfaction.

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