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16 Vascular Laser and Light Treatments

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Abstract

This chapter provides an overview of vascular targeting light treatments applied to treatment of commonly encountered cutaneous vascular lesions, specifically port wine birthmarks (PWBs), infantile hemangiomas (IHs), and telangiectasias. Evidence-based recommendations are provided regarding light-based treatment effectiveness, preoperative evaluation, treatment techniques, safety, and postoperative management. We also discuss device and drug combinations which have been utilized including photodynamic therapy or laser in combination with antiangiogenic agents for PWBs and beta-blockers with lasers for IHs. This chapter provides a practical, concise, and evidence-based guide for the utilization of vascular-specific laser treatments available today.

Keywords

Pulsed dye laser · Nd:YAG · Intense pulsed light (IPL) · Alexandrite · Port wine birthmarks/stains · Infantile hemangiomas · Telangiectasias

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Introduction

One of the first applications of lasers in dermatology was the treatment of port wine birthmarks (PWBs). Vascular-specific lasers such as argon lasers were used in the 1960s and improved PWBs but caused an unacceptably high incidence of scarring, due to the relatively non-specific heating of skin. Anderson and Parrish published their landmark paper on selective photothermolysis [1] in 1983, which proposed a way to confine thermal injury to the target of interest, while minimizing damage to surrounding tissue, reducing scarring and pigmentary change. Three laser parameters are important to selective photothermolysis: laser wavelength, pulse duration, and fluence. The wavelength should have preferential absorption for the targeted chromophore. In the case of vascular lesions, this is oxyhemoglobin, which has the greatest absorption peaks at 418, 542, and 577 nm (Fig. 16.1). Pulse duration should be matched to the target size with short durations for smaller targets and longer pulse durations for longer targets. In the case of vascular lesions, blood vessels are relatively large targets, and millisecond pulse durations are used. Fluence is the energy per unit area and must be adequate to cause damage to the target, but not excessive, which could result in nonselective injury.

The pulsed dye laser (PDL) (577–600 nm) was developed in the 1960s and provided the

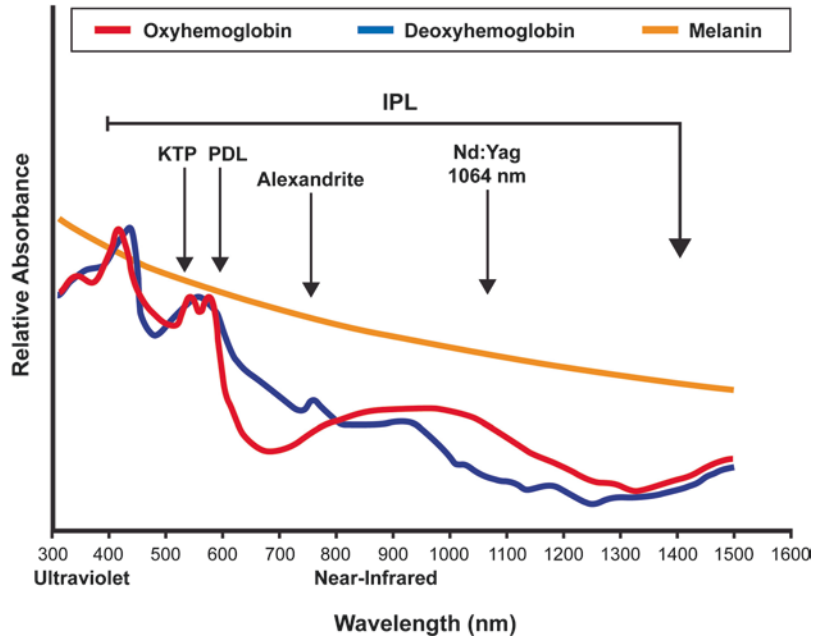

Fig. 16.1 Relative absorbance curves of vascular lasers and light

necessary components for selective photothermolysis to target vascular lesions. Several advancements were made in this device over subsequent decades. PDLs with longer wavelengths (585 and 595 nm compared to the original 577 nm) allow for slighter greater depths of penetration. The ability to use longer pulse durations (3–40 ms as compared to 1.5 ms or less) allows treatment for some lesions such as telangiectasias with minimal purpura, which is advantageous for cosmetic treatments [2 (2b)].

Epidermal cooling was introduced in the 1990s to protect the skin surface and to minimize pigmentary change and scarring, while reducing patient discomfort. Use of epidermal cooling is especially advantageous in patients with dark skin types, where increased epidermal melanin prevents penetration of light to targeted dermal tissues. Epidermal cooling also allows the use of higher fluences to improve tissue effect. The three types of epidermal cooling used are cryogen spray cooling, contact cooling, and air cooling.

Other devices have also been used for vascular lesion treatment. Potassium titanyl phosphate (KTP) lasers use a neodymium:yttrium aluminum garnet (Nd:YAG) crystal frequency doubled with a KTP crystal to emit a wavelength of 532 nm. The depth of penetration is slightly less than that of PDLs given the shorter wavelength. There is also increased melanin absorption at the 532 nm wavelength. Longer wavelength lasers can penetrate up to 50–75% deeper into the skin and can be used to treat deeper lesions. The alexandrite laser at 755 nm is a good choice to treat deeper, more resistant venous lesions, as its wavelength is close to the deoxyhemoglobin absorption peak (Fig. 16.1). Near-infrared diode (800–810 nm, 940 nm) devices are also used successfully for vascular targeting. The Nd:YAG laser can be used to treat vascular lesions by targeting the secondary, lower peak for the absorption of light by oxyhemoglobin (Fig. 16.1). It is important to note that the absolute absorption of hemoglobin is lower, requiring the use of higher fluences, which increases the risk of tissue damage and scarring. As such, these devices should be used with caution and are best used by clinicians with extensive experience. Intense pulsed light (IPL) devices emit polychromatic noncoherent broadband light from 420 to 1400 nm with varying pulse durations. Filters are implemented to remove unwanted shorter wavelengths to treat

vascular lesions with blue-green to yellow wavelengths. Dual wavelength or energy devices such as PDL combined with Nd:YAG (595 and 1064 nm) and PDL combined with radiofrequency energy are also available.

When selecting a device and treatment parameters, the user should keep in mind the type of lesion, the depth of the lesion, and the patient characteristics such as skin type. As an example, since the PDL penetrates 0.5–1.2 mm into the skin, it is efficacious for treating vascular lesions in the superficial dermis [3] and is most easily used in patients with lighter skin types, although settings can be adjusted (e.g., lower energies and longer pulse durations) for patients with dark skin types. Near-infrared and infrared wavelengths can be used to treat deeper lesions; however, as noted above, there is increased risk.

Indications for Vascular Lasers and Light Treatments

A diverse range of cutaneous vascular lesions can be treated with light-based devices. We describe some specific indications below.

Port Wine Birthmarks

Port wine birthmarks (PWBs) are congenital capillary malformations characterized by erythematous to violaceous patches. PWB vessels vary in size from 7 to 300 μm, with older patients tending to have larger vessels. PWBs are found in approximately 0.3% of newborns. They are commonly found on the head or neck, but can occur anywhere throughout the body. Over decades, lesions may thicken and develop papules and nodules [4, 5 (4, 4)]. Tissue hypertrophy, which can occasionally occur at birth, has been associated with 60–70% of lesions by the fifth decade of life. PWBs can be associated with various syndromes such as Sturge–Weber syndrome, which involves a facial PWB with associated ophthalmologic and/or neurologic abnormalities including glaucoma, seizures, and developmental delay. PWBs can also occur in association with arteriovenous malformations in Klippel–Trénaunay–Weber and Parkes Weber syndromes as well as in capillary malformation–arteriovenous malformation syndrome. Many patients seek treatment for these lesions due to the psychosocial or functional impact. Laser therapy is the standard of care treatment for PWBs.

Infantile Hemangiomas

Infantile hemangiomas (IHs) are the most common benign vascular tumors in children, occurring in 4–10% of infants. IHs are three times more common in females. Lesions are present at birth or become evident during the first several weeks of life. Sixty percent of lesions arise on the head and neck. Hemangiomas are characterized as localized or segmental, and as superficial (red papules or plaques), deep (blue or skin colored nodules), or mixed [6 (2a)]. Associated syndromes need to be considered when evaluating patients with IHs. PHACES syndrome needs to be considered in large segmental facial IH and involves posterior fossa malformations, IH, arterial anomalies, coarctation of the aorta, eye abnormalities, and sternal or supraumbilical raphe. LUMBAR syndrome includes **l**ower body infantile hemangiomas with **u**rogenital anomalies and **u**lceration, **m**yelopathy, **b**ony deformities, along with **a**norectal, **a**rterial, and **r**enal anomalies. Diffuse neonatal hemangiomatosis involves multiple skin hemangiomas and an associated risk of visceral hemangiomas.

Most IHs proliferate, often rapidly, until 6–9 months of life. Lesions then stabilize and begin to regress, with the majority of lesions regressing by 9 years of age, although recent studies suggest this may occur sooner [7 (1a)]. Some IHs leave behind residual fibrofatty tissue, atrophy, or telangiectasias. Small, non-ulcerated lesions in a non-cosmetically sensitive area may not require treatment. Treatment is needed for lesions that affect an important function (vision, feeding etc.), ulcerated lesions (as these are very painful), and for lesions that are in cosmetically sensitive areas and are likely to

result in scarring. Common locations of IHs that are indicated for treatment include lesions on the face or in the anogenital region. Treatment should be aimed at stopping progression of lesions early on to minimize tissue damage and therefore avoiding the need for long-term treatment in the future. Topical therapies (such as topical timolol), systemic medications (especially beta-blockers such as propranolol), and occasionally surgical intervention are used for lesions that ulcerate or impact functionality, such as feeding or vision. Beta-blockers are currently the standard of care for IHs, for which treatment is recommended. Laser therapy may be beneficial, especially for superficial or ulcerated lesions. Laser therapy is often used in combination with topical or systemic medications. Vascular targeting and fractioned lasers are commonly used to remove residual skin changes after involution.

Telangiectasias

Telangiectasias are common lesions that present as 0.1–1-mm diameter vascular dilatations that are visible on the skin anywhere on the body but especially on the face, around the nose, the cheeks, and the chin. They may occur in an acquired fashion in the setting of other conditions including cutaneous photodamage, rosacea, connective tissue or liver disease, radiation dermatitis, and post-long-term topical corticosteroid therapy [8 (2a)]. Numerous congenital conditions are associated with telangiectasias including hereditary hemorrhagic telangiectasia (HHT), Osler-Weber-Rendu syndrome, and ataxia-telangiectasia. Facial redness is a common complaint in patients with many telangiectasias.

Telangiectasias and resultant facial redness often do not require treatment from a medical standpoint, but some lesions, especially those associated with syndromes, may bleed. Telangiectasias can be treated for cosmetic purposes. Lasers provide quick and effective therapy. New telangiectasias often develop with time, and repeat treatments are often beneficial.

Effectiveness of Vascular Laser and Light Treatments

Port Wine Birthmarks

PDLs are commonly used to treat PWBs, with many studies demonstrating efficacy [9–14 (2b, 2b, 3b, 2b, 2b, 4)]. Multiple treatments are required to achieve maximum lightening of PWBs (15–20 or more are not uncommon), and complete clearance is uncommon [9–11 (2b, 2b, 3b)]. In 1 study of 76 patients, 79% clinical improvement was reported over an average of 9 PDL treatments [12 (2b)]. Factors that lead to improved response to PDL treatments of PWBs include small size (<20 cm^2), a location directly above a bony area (particularly the central forehead), and treatment at a young age [13 (2b)]. One study on 49 infants, all of whom started laser treatment before the age of 6 months, found an average clearance of nearly 90% after 1 year [14 (4)]. Additional studies have also indicated that earlier treatment of PWBs might allow for better results with fewer total treatments [15–18 (2b, 2b, 2b, 3b)]. Greater efficacy of treatment in young children may be related to increased hemoglobin concentration in the first 6–12 months of life and the presence of thinner skin and smaller lesion vessels in infants as compared to older individuals. Studies have shown that PWBs located on the trunk, extremities [19 (2a)], and central face (medial cheek, upper lip, nose) [20], and those lesions that are violaceous or nodular [21 (2b)], are more difficult to treat.

Lesions may recur after treatment. In a 10-year follow-up study of 51 patients treated with PDLs for PWBs, lesions were found to be significantly darker at follow-up than at the time of the last treatment. Lesions did remain significantly lighter than prior to initial therapy [22 (4)].

Infantile Hemangiomas

As noted above, beta-blockers are currently the standard-of-care treatment for IHs. When lasers are used, PDLs are a common laser used for the treatment of infantile hemangiomas. Study results

vary on the efficacy of treatment. Variability in study results is likely due to the natural course of these lesions (regression with time) and the range of laser parameters that have been used. Recent studies that suggest early treatment with PDLs can halt further growth and facilitate a transition to the involution phase, with minimal risk of adverse effects, when appropriate settings are used and patients are selected correctly. In a retrospective study of 90 patients, treatment with a 595-nm PDL with cooling led to 85% clearance of color and 64% resolution of thickness [23 (2a)]. Superficial IHs, as compared to deeper lesions, respond better. This is due to the limited depth of penetration of PDL light. A prospective study of 165 patients showed complete clearance of superficial IHs, while no mixed superficial-deep lesions exhibited complete clearance [24 (2b)].

PDL is also beneficial for treatment of ulcerated hemangiomas, especially in the anogenital area. A study on 78 patients with ulcerated hemangiomas showed that 91% improved after a mean of 2 PDL treatments [25 (2b)].

Propranolol can be used in combination with PDL. A retrospective study showed that complete clearance occurred more commonly when IHs were treated with propranolol and PDLs concurrently compared with IHs treated with propranolol followed by PDLs and IHs treated with propranolol alone [26 (2a)]. The same study also showed that clearance occurred at 92 days with combined therapy as opposed to 288 days for propranolol alone.

Telangiectasias

Many different light sources are effective in treating telangiectasias including PDLs, long-pulsed 532-nm lasers and intense pulsed light. PDL treatment with shorter pulse durations generally results in temporary purpura. Longer pulse durations, greater than 6 ms, can decrease resultant purpura, but more treatment sessions are usually needed. Two studies involving patients with facial telangiectasias and erythema showed that fluences that induce purpura were more effective at reducing the appearance of telangiectasias, although subpurpuric fluences did reduce surrounding erythema [27, 28 (3b, 2b)]. Vessels around the nasal ala are more difficult to treat. One study showed that cautious stacking of non-purpuric PDL settings resulted in successful resolution after PDL alone [29 (3b)]. Follow-up treatments are often required as telangiectasias can recur or new lesions develop with time.

Preoperative Evaluation

An initial consultation is important to determine the correct diagnosis, to assess if additional work-up is needed, and to discuss treatment options. If laser therapy is planned, expectations for treatment, the need for multiple sessions, and risks of treatment as well as benefits should be discussed. It also needs to be determined whether anesthesia will be used for the procedure, and if so, anesthesia options should also be discussed. Expected post-treatment effects including erythema, purpura, and swelling should be described and aftercare, including sun protection and avoidance of trauma should be addressed. Photos should be taken prior to each treatment to check and assess improvement.

As mentioned earlier, associated syndromes need to be considered when evaluating patients with PWBs, infantile hemangiomas, and telangiectasias. For PWBs, if Sturge-Weber syndrome is suspected, then ophthalmology and neurology referrals may be appropriate. Imaging studies including ultrasound (in the first year of life) or magnetic resonance imaging (MRI) may also be appropriate to assess central nervous system involvement. For large facial IH, features of PHACES syndrome should be assessed through utilization of imaging studies including echocardiogram and brain MRI/MR angiogram. An eye exam by an ophthalmologist may be warranted. If hemangiomas of the beard area (mandibular innervation area of the trigeminal nerve) are seen, referral to an otolaryngologist is warranted to assess for upper airway hemangiomas, which can cause airway obstruction. Urologic workup including imaging (ultrasound, MRI) of the pelvis and perineum to assess for abnormalities in the kidney, urinary tract, and genitalia should be considered if

LUMBAR syndrome is suspected. Work up is not generally required for telangiectasias unless a genetic syndrome such as HHT is suspected.

Prior to treatment, the question of whether to use local/general anesthesia or pain medications should be addressed. Non-steroidal anti-inflammatory drugs (NSAIDs) should be avoided as they inhibit clotting and can minimize treatment effects. Topical anesthetics can be used, but vasoconstriction and lesion blanching may occur with some topicals, which could potentially decrease the efficacy of treatments. Injected anesthesia, nerve blocks, and local injections can be considered [30 (2a)]. One study showed that complete nerve block, when utilized for laser treatment of cutaneous lesions, led to excellent pain control in 96% of cases, while complications, including vasovagal syncope, swelling, and neurapraxia occurred in only 1.1% of cases and were generally mild and transient [31 (2b)]. Early treatment of PWBs and IHs is often beneficial, and general anesthesia may be considered for treatment of infants and young children as treatments are uncomfortable and require eye protection and limited movement of the patient. In our clinic, general anesthesia is used in some children over 6 months of age; it offers the advantage of minimizing fear and pain in children who will need lengthy and/or multiple procedures for large lesions. One study reported no serious adverse events in 881 dermatologic procedures performed on children with an age range of 2 months to 18 years [32 (2b)]. Other studies have shown little risk during the procedure if general anesthesia is performed with pediatric anesthesiologists [33, 34 (2b, 2b)]. In recent years, the risk of developmental delay when general anesthesia is used in children less than 3 years of age has been a concern. Some of the concerns were based on animal studies. The US Food and Drug Administration (FDA) recently released a warning [35] as these animal research studies have shown that there may be risks, including neurodegenerative changes in the developing brain, with general anesthesia in the first few months to a year of life. At the current time, the FDA states that there is insufficient data to determine the clinical relevance of these findings and further studies are needed to assess the long-term effects. There have been some recent large clinical studies, which did not find significant increased risk of development delay associated with general anesthesia procedures in young children [36, 37 (2b, 1b)], but additional studies are pending. However, all potential risks should be discussed with parents, so informed decisions can be made.

Immediately following laser treatment for vascular lesions, local swelling and pain similar to a sunburn is common. Aftercare including elevation, ice application, over-the-counter oral analgesics (if not contraindicated acetaminophen is preferable to NSAIDs as the latter could affect treatment effects and increase bruising), mild topical emollients (such as petrolatum), sun avoidance/protection, and avoidance of trauma all are beneficial for decreasing the likelihood of patient discomfort, hyperpigmentation, and scarring [38 (2a)].

Best Techniques and Performance

Use of lasers always requires appropriate eye protection. All present in the room must wear appropriate goggles. Patients can wear goggles if non-facial areas are treated, if goggles of the correct size are available, and if the patient is unlikely to remove them. Young children often require more secure eye protection, such as laser safe eye pads (adhesive pads with metal to protect the eyes) and gauze or securely placed overlying metal eye shields. If the skin inside the orbital rim is to be treated, corneal shields are needed. These can be placed using anesthetic drops approved for ophthalmologic indications and lubricant. Use of lubricant may cause post-procedure blurriness, so patients should have an accompanying driver or make sure lubricant is rinsed out prior to driving. There is a small risk of corneal eye injury with placement of these shields, so this should be done with care.

Laser parameters vary based on type of lesion, lesion characteristics and location, and patient skin type. Large spot sizes offer the advantage of minimizing light scatter and allows for increased penetration of light. It may be advisable to use

lower fluences and longer pulse durations in those with darker skin types. Epidermal cooling techniques are used concurrently for all laser treatments of vascular lesions.

Port Wine Birthmarks

PDLs are commonly used for PWBs. An example of parameters include [39 (2a)]:

- Wavelength: 585–595 nm
- Pulse duration: 0.45–10 ms
- Fluence: 4.5–12 J/cm^2 (settings need to be individualized for each device; lower energies are generally used with larger spot sizes)
- Spot size: at least 7 mm
- Appropriate epidermal cooling

Treatment parameters for PWBs with PDLs vary to some degree with each specific device. Appropriate initial PDL fluence settings vary largely due to individual patient characteristics including skin color, lesion morphology, and lesion location. Lower initial fluences are typically used for young children, individuals with dark skin (due to risks of hyper/hypopigmentation), and lesions in areas at higher risk for cutaneous damage, such as the neck or eyelid. Fluences can be increased by 0.5 J/cm^2 during subsequent treatment visits, if adequate response has not been obtained and there are no adverse effects [38 (2a)]. It is important to know desired treatment end points for all laser treatments. For PDL treatment of PWBs, purpura without cutaneous whitening or graying is the desired endpoint.

Other devices can also be used. The 532-nm frequency-doubled Nd:YAG is one option. In one study, the 532-nm Nd:YAG (9.5–20 J/cm^2, pulse duration 15–50 ms, 2–6 mm spot size, unspecified integrated cooling system utilized) generated 50% improvement from baseline in PWBs resistant to other laser treatments [40 (2b)]. Another study found that lesion color improved at least 25% in 53% of patients after treatment with a 532-nm frequency-doubled Nd:YAG (5–50 J/cm^2, pulse duration 1–50 ms, variable spot sizes, cooling method unspecified) [41 (2b)].

Near-infrared lasers including the alexandrite and 1064-nm Nd:YAG lasers are helpful for violaceous, nodular, or hypertrophic lesions [42, 43 (3b, 4)]. Scarring is more likely to occur, as higher fluences are needed to target the vasculature. This is especially true of the Nd:YAG laser which preferentially targets arterial blood, as opposed to the venous blood which is present in PWBs. Studies of the Alexandrite 755-nm laser have demonstrated good efficacy for hypertrophic PWBs resistant to PDLs, with clinical observations showing mild-to-moderate PWB lightening (40–100 J/cm^2, pulse duration 1.5 ms, 8 mm spot size, dynamic cooling device utilized), (35–100 J/cm^2, pulse duration 3 ms, 8–12 mm spot size, forced cold-air cooling) [44, 43 (5, 4)]. One study demonstrated good to excellent improvement with only a few treatments using the long-pulsed 1064-nm Nd:YAG laser in most patients treated for hypertrophic PWBs (100–240 J/cm^2, pulse duration 30 ms, 5 mm spot size, liquid cooling via stainless steel hand piece). Lesion hypertrophy responded better than color, and authors recommended combining with PDL treatment to further improve coloration of lesions [45 (2b)].

IPLs can also be utilized to treat PWBs. A study by Faurschou et al. found that both PDLs and IPLs lightened PWBs and could be used safely without adverse events (595-nm PDL, 7–14 J/cm^2, pulse duration 0.45–1.5 ms, 7–10 mm spot size; dynamic cooling device at 30-ms spray duration and 20-ms delay; IPL, 500–1400 nm, 22–46 J/cm^2, pulse duration 5–10 ms; handpiece equipped with sapphire contact cooling). In this study, more patients experienced better clearance rates with PDL (75%) as compared to IPL (30%) [46 (1b)]. Another study showed that in a group of 15 patients with PDL-resistant PWBs, 40% achieved more than 75% clearance with IPL (555–950 nm, 13–22 J/cm^2, pulse duration 8–30 ms, optical coupling gel utilized) [47, (3b)]. IPL was found to be safe and efficient in the treatment of PDL-resistant PWBs, except for those located in the V2 type distribution of the face as these lesions in the central part of the face are located deeper in the skin, and thus insufficient energy may have reached these areas. Furthermore, shorter pulse durations may be ben-

eficial for these lesions given the average size of vessels.

PWB treatment sessions are typically scheduled at 4–6-week intervals, and ten or more treatment sessions are often required. Shorter intervals can be considered as described in a retrospective study of 24 infants with facial PWBs where treatment intervals of 2, 3, or 4 weeks were effective and were well-tolerated [48 (3b)]. Darker skin types or lesions in the extremities may require longer intervals between treatments, ranging from 6 to 8 weeks.

Pulses can be overlapped by 10% [38 (2a)]. Multiple passes during the same treatment session may benefit PWBs [49] but should be approached with caution as this approach can increase the risk of adverse effects including pigmentary change (which can be permanent) and scarring.

Infantile Hemangiomas

As noted above, PDLs are the most common lasers used for the treatment of IHs. Commonly used parameters include (parameters vary by device):

- Wavelength: 585–595 nm
- Fluence: 5–7.5 J/cm^2
- Pulse duration: 0.45–6 ms
- Spot size: 5–10 mm

The growth phase of the IH must be taken into account. Proliferating lesions have a higher risk of ulceration and lower fluences must be used during this period. Lower fluences are also advisable in darker skin types and areas of thin skin, such as the eyelids. As mentioned earlier, skin cooling techniques are vital as they allow for higher fluences while minimizing the risks of epidermal damage. Multiple treatments are usually required and may be done at 2–4-week intervals for rapidly proliferating/ulcerated lesions or 4–6-week intervals for stable/involuting lesions.

Other laser options that have also been implemented to successfully treat IHs include frequency-doubled Nd:YAG. A retrospective study of 50 infants were treated with a 585 nm PDL (5.3–6.8 J/cm^2, pulse duration 0.3–0.45 ms, 7 mm spot size, chilled tip cooling utilized) or a 532-nm frequency-doubled Nd:YAG (20 J/cm^2, pulse duration 1–50 ms, 5 mm spot size, chilled tip cooling utilized). PDL was found to be more effective, where cessation of growth or improvement occurred in 93% (average of 3 treatments) of lesions compared to 70% (average of 2.6 treatments) of lesions using the 532-nm Nd:YAG laser [50 (2b)]. The 1064-nm Nd:YAG has been suggested for use with thicker hemangiomas given its greater depth of penetration. An uncontrolled study showed that sequential 595-nm PDL (7–15 J/cm^2, 10–40 ms pulse duration, variable spot sizes, unknown if cooling utilized) with 1064-nm Nd:YAG (50–100 J/cm^2, 10–40 ms pulse duration, variable spot sizes, cooling not described) treatments led to excellent improvement in the majority of hemangiomas involving the head and neck [51 (3b)]. There is a high risk of scarring with the 1064-nm Nd:YAG, and the authors never use this device for IHs and would recommend that use of this device only be considered by experienced users. For IHs with a superficial and deep component, beta-blockers in combination with PDLs may be a good option.

After involution, IHs can leave behind telangiectasias or residual fibrofatty tissue. Telangiectasias can be treated with PDL, and texture changes have been shown to improve with ablative or non-ablative fractional resurfacing (NAFR). A case report showed excellent skin texture improvement along with a substantial decrease of residual tissue bulk using NAFR (fractionated 1440-nm erbium-doped fiber laser, 25 J/cm^2, 15 mm spot size, forced air device cooling utilized) [52 (5)]. A series of case reports have shown that ablative fractional CO_2 lasers have promise in the flattening of fibrofatty residual tissue with 50–75% improvement in color, texture, and overall appearance (ablative fractional CO_2 laser, 20–40 J/cm^2, 15 mm spot size) [53 (5)].

Telangiectasias

Lasers are the most common treatment for multiple or large areas of telangiectasias and can also

be used when other modalities, such as electrocautery, have failed. Multiple treatments (2–4) are often required to achieve the best results, especially when non–purpuric settings are utilized [27, 28 (3b, 3b)].

Commonly used parameters for PDL include (parameters vary by device):

- Wavelength: 595 nm
- Fluence: varies depending on spot size and pulse duration
- Pulse duration: 1.5–20 ms
- Spot size: 7–12 mm
- Appropriate epidermal cooling

Multiple passes or pulse stacking can be considered when longer pulse durations are used [49, 54 (3b, 2b)]. Telangiectasias respond in fewer treatment sessions when purpuric settings are used, but cosmetic patients often prefer to avoid purpura. Vessel clearance and purpura indicate appropriate end points of therapy. Follow-up treatments are usually necessary.

The 532-nm frequency-doubled Nd:YAG laser is also commonly used and effective. The 532-nm laser can be used to treat facial telangiectasias with minimal to no purpura. In a study of 66 patients with facial telangiectasias, a 532-nm Nd:YAG laser (16–22.5 J/cm^2, pulse duration 15–30 ms, 5–7 mm spot size, cooling not specified) resulted in 75–100% clearance of telangiectasias in >90% of subjects after one treatment [55 (2b)]. A disadvantage of this laser is increased melanin absorption, resulting in a greater risk for adverse effects in darker skin types.

IPL can also be used very successfully for telangiectasias. One study showed that IPL-treated telangiectasias (570 nm cut-off filter, 40–43 J/cm^2, 4 ms pulse duration, ice application for 10 min following procedure) achieved 75–100% clearance with minimal purpura. Results correlated with operator experience [56 (2b)].

The long pulsed 1064 nm Nd:YAG laser can also be used for facial telangiectasias. One study demonstrated 95–100% clearing of facial telangiectasias after only one treatment (100 J/cm^2, 10 ms pulse duration, 2.5–7 mm spot sizes, external epidermal cooling device utilized) [57 (2b)]. Again there is an increased risk of scarring with the device, and it should be used cautiously by operators experienced with 1064-nm Nd:YAG use and end points.

Safety

Lasers are safe for use in patients of all ages, including young infants. Knowledge about desired end points and careful monitoring of the skin during and after the procedure are the best ways to avoid undesired adverse effects [58 (4)]. When using the PDL, temporary purpura is expected when treating PWBs and IHs. Purpura usually resolves within 7–14 days [39 (2a)]. A gray color may indicate epidermal damage, and treatment should be stopped or settings adjusted. The 755-nm alexandrite laser has a treatment end point of a transient gray discoloration of the skin followed by purpura. Persistent gray discoloration is not desired and may result in adverse effects including scarring.

Potential adverse effects of laser therapy include blistering, erosions or ulcerations, scarring, and hyper- or hypopigmentation. There is low risk of pigment changes and scarring with yellow wavelength lasers, particularly if appropriate cooling and longer pulse durations are implemented as mentioned above [59 (2b)]. Darkly pigmented skin and extremity lesions have a higher risk of adverse effects. As noted above, proliferating IHs are at increased risk for ulceration, which often results in scarring, and treatment at this stage needs to be approached with caution [60 (4)]. Laser treatment of vascular lesions with longer wavelengths, especially the 1064-nm Nd:YAG, carries increased risk of ulceration and scarring and should be considered only by more experienced laser surgeons.

Hair loss can occur with any millisecond laser or IPL, especially in patients with darker hair, and as such, hair-bearing areas are generally avoided. Applying aloe vera gel or Vaseline to the eyebrows and eyelashes when treating near these areas can help protect the superficial follicles that are most susceptible to hair loss during laser treatment.

Appropriate eye protection as described above is essential and allows avoidance of eye injury.

Postoperative Care and Follow-Up

Laser treatment sessions for PWBs are typically scheduled at 4–6 week intervals, and many treatments are often required [38 (2a)]. Multiple treatments are also required for IHs and may be done at 2–4 week intervals for rapidly proliferating/ulcerated lesions or 4–6-week intervals for stable/involuting lesions. Multiple treatments may also be required to achieve the best results for telangiectasias and can be performed at 4–6-week intervals.

During follow-up visits, patients or their parents should be asked about bruising or blistering, and the skin should be evaluated for scarring, atrophy, and dyspigmentation. As previously noted, patients with darker skin tones are at greater risk for pigmentary change and scarring. Daily application of a bleaching cream, such as hydroquinone 4%, after the resolution of any purpura and between treatment sessions can be used to decrease this risk or to treat post-inflammatory hyperpigmentation. Sun protection for treatment areas before and after treatment can decrease melanin and improve treatment results (greater efficacy with diminished risk of adverse effects).

Alternative Procedures and Modifications

Port Wine Birthmarks

Lasers and light-based devices are clearly the standard of care for PWBs in the United States and Europe. Photodynamic therapy (PDT) has also been used to treat PWBs. It is most commonly used in China. One study found PDT to be at least as effective as PDL in terms of blanching rate and side effects for the treatment of neck and upper arm lesions [61 (3b)]. Another study determined that fewer treatment sessions were required using PDT for PWBs compared to PDL for the successful treatment of superficial lesions and improvement of thick lesions [62 (3b)]. PDT has rarely been used in the United States as the administration of systemic photosensitizers results in prolonged photosensitivity for weeks after the procedure, and there is a risk of multiple side effects including deep vascular injury, which can result in significant scarring [62 (3b)]. Optimization of the parameters of PDT or its combination with PDL may improve the utility of PDT for PWBs [63–65 (2b, 3b, 3a)].

Angiogenesis inhibitors, such as rapamycin, in combination with PDL, have also been evaluated. This is an off-label use of rapamycin. Topical and oral formulations of rapamycin have been studied; use of topically applied medication has the benefit of minimal systemic absorption and few side effects. Multiple studies have demonstrated that topical rapamycin can suppress angiogenesis pathways induced by PDL [66, 67 (1b, 5)] and that the combination of topical rapamycin and PDL can, at least in some cases, provide improved treatment results. Further studies are necessary to determine the effectiveness of combined device/antiangiogenic agents and to find an optimal combination and protocol.

Infantile Hemangiomas

Oral propranolol has been established as a safe and effective treatment and is the first-line therapy for IHs. Clinicians treating IHs must be familiar with and consider the option of beta-blockers for IHs. In a meta-analysis, propranolol showed superior reduction in IH size compared to observation, placebo, and oral corticosteroids [68 (2a)]. A recent randomized, controlled trial on 460 infants showed propranolol to be effective in doses up to 3 mg/kg/day for 6 months [69 (1b)]. Side effects of nonselective beta-blockers include dizziness, weakness, trouble breathing, shortness of breath, chest pain, changes in heart rate, and seizures. Beta-blockers are generally well tolerated in infants for which there are no contraindica-

tions for treatment. Topical beta-blockers are another option and have also been demonstrated to provide benefit in treatment of IHs. A randomized controlled trial using topical timolol gel on superficial hemangiomas on 41 infants aged 5–24 weeks showed significant color change and reduction in size after 24 weeks of treatment with minimal variation in blood pressure or heart rate [70 (1b)]. Another randomized controlled trial using atenolol, a cardio-selective beta-blocker with less respiratory comorbidities than propranolol, showed that oral atenolol was at least as effective as oral propranolol in the treatment of IH [71 (2b)].

Combining beta-blockers with laser may achieve enhanced results compared to either treatment option alone. A study by Reddy et al. showed that facial IH treated with both oral propranolol and PDL showed more complete resolution with propranolol treatment needed for a shorter period of time (595-nm PDL, 8.5–12 J/cm^2, pulse duration 0.45–1.5 ms, 7 mm spot size, dynamic cooling device spray duration of 30 ms and delay of 30 ms) [72 (2b)]. In another randomized, controlled trial, timolol plus PDL was superior to PDL alone in effecting resolution of IHs (585-nm PDL, 9 J/cm^2, pulse duration 0.45 ms, 5 mm spot size, no cooling) described [73 (1b)].

Telangiectasias

Telangiectasias often do not require treatment. Laser therapy is a quick and effective treatment, when desired. Electrocautery can be considered as an alternative when there are a small number of superficial lesions and/or a laser is not available.

Observations and Recommendations (Table 16.1)

Table 16.1 Evidence-based summary: Grading of Recommendations Assessment, Development and Evaluation (GRADE)

Findings	GRADE score: quality of evidence
Vascular lesions including PWBs, IHs, and telangiectasias are among the most common indications for laser treatments	B
Epidermal cooling techniques minimize pigmentary changes and scarring and are important to use during laser treatment of cutaneous vascular lesions	B
The risk of scarring and pigmentary change is increased in patients with darker skin tones and when using deeper penetrating lasers	C
Port wine birthmarks	
PDLs are commonly used for PWBs, but multiple vascular targeting devices can be used	B
Resistant, nodular and/or hypertrophic lesions can be treated with deeper penetrating lasers but should be used cautiously by experienced clinicians due to increased risk of adverse effects	C
Multiple treatments are required and some recurrence is common	C
Treatment at an early age may enhance response	C
Infantile hemangiomas	
Infantile hemangiomas that are superficial are the best candidates for laser therapy	C
PDL is the most common laser used for treatment	C
Combining beta-blockers with laser therapy should be considered and may achieve quicker and more complete response	B
Telangiectasias	
Laser therapy is an effective, and when performed correctly, safe treatment for telangiectasias	B
Multiple devices can be used including PDL, 532-nm lasers, and IPL	B
Development of new lesions is common	B

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Self-Assessment Questions

1. Which of the following increases the potential for side effects including discoloration, ulceration, or scarring when treating vascular lesions?
   (a) Use of longer wavelength lasers (such as 1064 nm)
   (b) Use of small spot size with high fluences
   (c) Turning off epidermal cooling
   (d) Treatment of patients with darker skin types
   (e) All of the above
2. All are factors that portend to an improved response to PDL treatment of PWBs except:
   (a) Small size (<20 cm^2)
   (b) Nodular lesions
   (c) Treatment at a young age
   (d) Lesion above a bony area
   (e) Lesion near the peripheral face
3. Which of the following statements regarding laser treatment of PWBs is false?
   (a) A desired end point is purpura without cutaneous whitening/graying.
   (b) The 755-nm alexandrite laser can be used for hypertrophic lesions resistant to PDL treatment.
   (c) Both PDL and IPL treatments have been shown to produce good clearance rates of PWBs.
   (d) Lesions may recur after treatment.
   (e) None; all of the above statements are true.
4. All of the following are indications to treat IHs early except for:
   (a) Lesions in the anogenital region
   (b) Lesions near the mouth
   (c) Non-ulcerated lesions near an extremity
   (d) Ulcerating lesions
   (e) Lesions near an eye
5. Which of the following is/are false regarding the treatment of IHs?
   (a) Propranolol used in combination with PDL for IH has been shown to be as efficacious as propranolol alone.
   (b) It has been shown that topical timolol plus PDL is superior to PDL alone.
   (c) PDL is the first-line therapy for IH.
   (d) Mixed superficial–deep lesions treated with PDL have not been shown to exhibit complete clearance.
   (e) a and c.
6. Which of the following devices can be used to treat telangiectasias?
   (a) PDL
   (b) Long-pulsed 532-nm laser
   (c) IPL
   (d) Long-pulsed 1064-nm laser
   (e) All of the above

Correct Answers

1. e: Risks of discoloration and scarring are higher with longer wavelengths such as the 1064-nm Nd:YAG and 755-nm alexandrite lasers. The use of large spot sizes, low fluences, and epidermal cooling techniques helps to minimize the risk of ulceration and scarring. Patients with darker skin types have increased melanin and are at higher risk of adverse effects.
2. b: Factors that lead to improved response to PDL treatments of PWBs include small size (<20 cm^2), a location directly above a bony area (particularly the central forehead), and treatment at a young age. Studies have shown that PWBs located on the trunk, extremities, central face (medial cheek, upper lip, nose) rather than on other facial areas, and those lesions that are violaceous or nodular are more difficult to treat.
3. e: For PDL treatment of PWBs, purpura without cutaneous whitening or graying is the desired end point. Other laser therapies can be utilized in patients who fail to improve with PDL therapy alone. Near-infrared lasers including the 1064-nm Nd:YAG and 755-nm alexandrite lasers have been shown to improve the appearance of hypertrophic PWBs, particularly lesions resistant to other laser treatments. More patients have experienced better clearance rates with PDL compared to IPL, but clearance rates following both treatments have shown good results. Lesions may recur after treatment. In a 10-year follow-up study of 51 patients treated with PDLs for PWBs, lesions were found to be significantly darker at follow-up than at the time of the last treatment, although the lesions did remain significantly lighter than prior to initial therapy.
4. c: Treatment of IH should be aimed at stopping progression of lesions early on to minimize tissue damage and therefore avoiding the need for long-term treatment in the future. Intervention is recommended for lesions that ulcerate or impact functionality, such as feeding or vision.
5. e: Propranolol can be used in combination with PDL. A retrospective study showed that complete clearance occurred more commonly when IHs were treated with propranolol and PDLs concurrently compared with IHs treated with propranolol followed by PDLs and IHs treated with propranolol alone. In a randomized, controlled trial, timolol plus PDL was superior to PDL alone in effecting resolution of IHs. Oral propranolol has been established as a safe and effective treatment and is the first-line therapy for IH (not PDL). In a meta-analysis, propranolol showed superior reduction in IH size compared to observation, placebo, and oral corticosteroids. Superficial IH, as compared to deeper lesions, responds better to PDL treatment. This is due to the limited depth of penetration of PDL light. Studies have shown complete clearance of superficial IH, while mixed superficial-deep lesions exhibited less complete clearance.
6. e: All of the above devices can be used to treat telangiectasias. Lasers are the most common treatment for multiple or large areas of telangiectasias and can also be used when other modalities, such as electrocautery, have failed. Treatment/device selection and settings should be individualized to conform to patient's skin type, vessel characteristics, and healing time tolerance.