Acta Dermatovenerol Croat 2010;18(3):201-208 REVIEW

Pulsed Dye Laser Treatment of Vascular Lesions in Childhood

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SUMMARY Almost all congenital vascular abnormalities affect the skin and are evident from birth or become so during the first few weeks of life. The two most common types of vascular birthmarks, hemangiomas and vascular malformations, may appear to be very similar but their course and treatment are different. Hemangiomas appear in the first few weeks of life and usually regress spontaneously over time. Vascular malformations are always present from birth even though they might not be apparent, never disappear and often grow during the person's lifetime and may vary extremely from high blood flow lesions, sometimes located in critical sites that may be life-threatening to asymptomatic spots of mere aesthetic concern. Laser therapy nowadays has become indispensable in the management of pediatric vascular lesions. With a proper balance of wavelength, energy density and pulse duration, the laser energy of thermo coagulation could be molded to effectively manage different lesions. Both dermatology and plastic surgery have been transformed by understanding vascular lesions biology and modern laser technology. As a result, we can now provide an optimal selective treatment with minimal collateral damage. Although alternatives such as the potassium titanyl phosphate (KTP), red/infrared (IR), or intense pulsed light lasers are available, pulsed dye lasers continue to be the standard of care for the majority of pediatric vascular lesions.

KEY WORDS: pulse dye laser, vascular birthmarks, laser therapy, hemangioma, port wine stain, childhood

BASIC FACTS ON PULSED DYE LASERS

The theory of selective photo-thermolysis introduced in 1983 by Anderson and Parrish (1) showed that laser energy could be specifically deposited within a target tissue (a chromophore) resulting in controlled thermal injury with minimal collateral damage. Energy penetration into the skin relies on the balance of absorption and energy scattering, so the proper selection of basic

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laser elements will provide an optimal therapy. In that way, laser therapy can be tailored to create maximum target tissue destruction with minimal injury to the neighboring tissue (1-5).

Wavelength must be selected according to the absorption pattern of the target in vascular lesions; the chromophore is typically oxyhemoglobin. Appropriate heating of intravascular oxyhemoglobin results in coagulation and surrounding vessel destruction. The **energy density** of the laser must be sufficient to heat target tissue to about 70 °C to injure it irreversibly within the allotted pulse duration interval (1-5). The chromophore thermal relaxation time must be greater than or equal to the selected pulse duration for effective therapy. Larger vessels are often resistant to moderate intervals of exposure, so excessive **pulse durations** allow heat to dissipate into the surrounding structures, which may result in scarring, permanent dyspigmentation, and poor photothermo-coagulation (6-9). The **spot size**, or laser light diameter used should not be larger than the target lesion. Increased beam diameters allow for greater tissue penetration, more uniform energy transmission, and more rapid treatment. Common spot sizes range from 7 to 10 mm (10-15). By **epidermal cooling** (ice-cubes, cold gel, chilled-air, pulsed cryogen, liquid cryogen sprays), higher levels of energy can be transmitted with minimized discomfort and improved therapeutic outcome (11-16).

Containing rhodamine dye, vascular pulsed dye laser (PDL) light emission may be stimulated by a xenon flash lamp to produce light at 585 to 600 nm in short (0.5 ms), long (1.5 ms) and very long (1.5 to 40 ms) pulses. Longer pulse duration is more appropriate for large-caliber vasculature and offers improved efficacy over shorter pulse-width for such lesions. For smaller vessels, short pulse durations are most effective, but longer pulse-widths can also yield results while minimizing bruising (16-19).

CONGENITAL VASCULAR ABNORMALITIES

Almost all congenital vascular abnormalities affect the skin and are evident from birth or become so during the first few weeks of life. The two most common types of vascular birthmarks, hemangiomas and vascular malformations, may appear to be very similar but their course and treatment are different.

Hemangiomas appear in the first few weeks of life and usually regress spontaneously over time. In general, most hemangiomas can be considered insignificant tumors that do not require treatment except for certain exceptional circumstances, and that represent an aesthetic rather than a medical problem. Nevertheless, they may have a large psychological impact in the family setting. Some hemangiomas with normal development may not involute and will persist throughout the person's life (Fig. 1).

Vascular malformations are always present from birth even though they might not be apparent, never disappear and often grow during the person's lifetime (20). They may vary extremely from high blood flow lesions, sometimes located in critical sites that may be life-threatening to asymptomatic spots of mere aesthetic concern. Despite of the low incidence of these disorders and therapeutic guideline difficulties, a multidisciplinary approach is necessary for proper patient management and follow-up (Fig. 2).

In 1982, Mulliken and Glowacki (21) published a

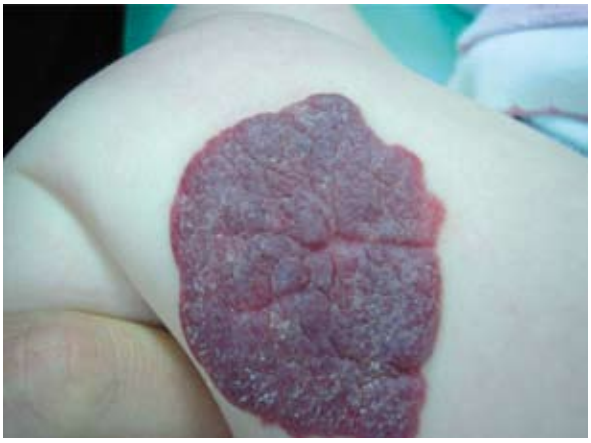

Figure 1. Lower extremity hemangioma

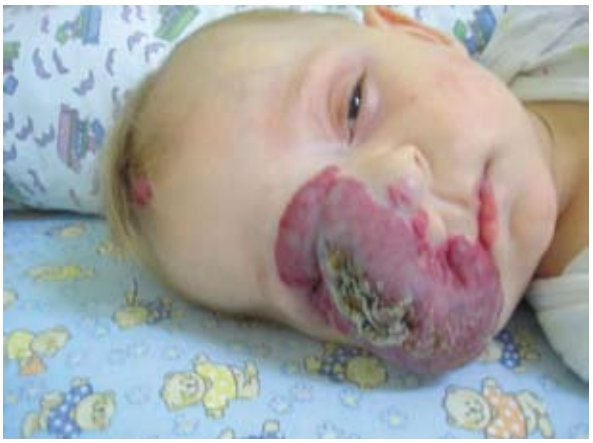

Figure 2. Ulcerated facial hemangioma

Table 1. Modified classification of the International Society for the Study of Vascular Anomalies (Rome, Italy, 1996)

Tumors	
Hemangiomas	Superficial (capillary or strawberry hemangiomas)
	Deep (cavernous hemangiomas)
	Combined
Other	Kaposiform hemangioendothelioma
	Tufted angioma
	Hemangiopericytoma
	Spindle-cell hemangioendothelioma
	Glomangiomas
	Pyogenic granuloma
	Kaposi sarcoma
	Angiosarcoma
Vascular malformations	
Single	Capillary (C) (port wine stain, nevus flammeus)
	Venous (V)
	Lymphatic (L) (lymphangioma, cystic hygroma)
	Arterial (A)
Combined	Arteriovenous fistula (AVF)
	Arteriovenous malformation (AVM)
	CLVM (includes most of the Klippel-Trenaunay syndromes)
	CVM (includes some cases of Klippel-Trenaunay syndrome)
	LVM, CAVM, CLAVM

biological classification of vascular lesions based on the main endothelial characteristics. Later redefined by Mulliken and Young (22), it was adopted by the International Society for the Study of Vascular Anomalies (ISSVA) in 1996 and it is the most widely used classification with minimal changes to the original version (Table 1). In 1998, the so-called Hamburg classification was published. This classification describes the malformation in terms of the predominant component of the vascular lesion, which is then classified as truncular or extratruncular according to the embryonic stage when the malformation begins to develop (23) (Table 2).

The diagnosis of vascular tumor is based on history and physical examination alone in about 95% of cases (24). Contrast magnetic resonance imaging (MRI) allows for precise localization of the lesion and can detect associated nervous system abnormalities (25). Ultrasound with Doppler interrogation is the most cost-effective and noninvasive imaging technique (26).

HEMANGIOMAS

Hemangiomas of infancy are the most common benign tumors of childhood, composed of proliferating endothelial tumor cells and usually manifested as cutaneous birthmarks, characterized by early, rapid proliferation and regression in the majority of cases (27). Hemangiomas result from abnormal changes in angiogenesis that lead to over-proliferation of vascular entities. Most hemangiomas develop sporadically and are believed to be the result of developmental errors that occur between the 4th and 10th week of gestation. Hemangiomas of infancy are present in up to 3% of newborns, but the incidence may be as high as 10%-12% in white children as the proliferative phase progresses in the first year of life (6). They affect females more than males with a 3:1 ratio (7,8). Approximately 30% of these birthmarks are apparent while the infant is in the newborn nursery and up to 90% are recognized within the first month of life. Their frequency tends to be higher in infants who are preterm, weighing less than 1500 g (7). Hemangiomas are most commonly located on the head and neck (59%), followed by the trunk (24%), lower extremities (10%), and upper

Table 2. Classification of vascular malformations (Hamburg, Germany, 1998)

Type of defect	Anatomic form	
	Truncular	Extratruncular
Mainly arterial	Aplasia Obstruction Dilation	Infiltrating Limited
Mainly venous	Aplasia Obstruction Dilation	Infiltrating Limited
Mainly arteriovenous shunt	Superficial arteriovenous fistula Deep arteriovenous fistula	Infiltrating Limited
Combined defects	Arterial and venous Hemolymphatic	Infiltrating Limited

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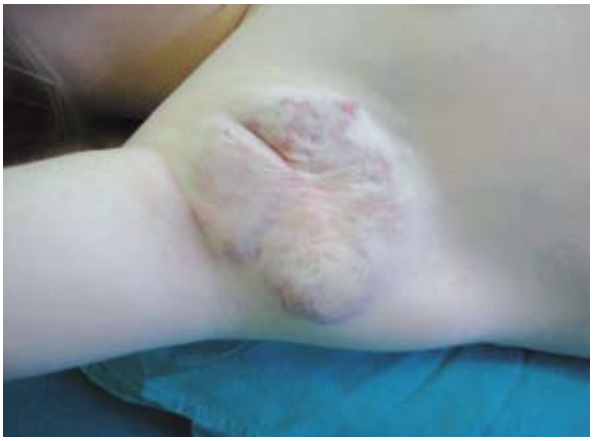

Figure 3. Axillar vascular anomaly

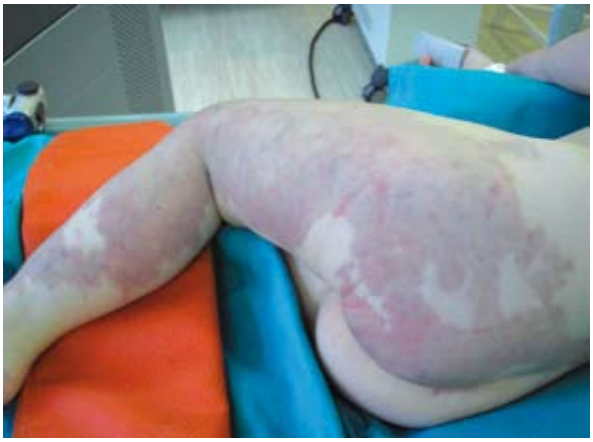

Figure 4. Port wine stain of lower extremity.

extremities (7%) (20). Most are less than 2.0 cm in diameter, but in some instances can cover large portions of the body.

Although the majority of hemangiomas begin to slowly involute by 1 year of age, complete resolution often takes 5 to 12 years. Regression typically occurs in 50% of patients by age 5, in 70% by age 7, and in 90% by age 9 (28-30). They can threaten vital life processes if located in certain areas of the body; many lesions are defined by a less predictable course, such as nasal tip or eyelid location, ulceration, sites associated with significant dysfunction, or lack of treatment response (28-30). They may also be part of larger syndromes associated with high rates of life-changing morbidity and mortality. Evidently, they can cause a tremendous amount of anxiety and psychological distress in parents that may also prompt PDL application (28-30) (Fig. 3).

VASCULAR MALFORMATIONS

Vascular malformations are benign, nontumorous lesions that are always present from birth, although they may not always be visible until weeks or months later (31). Their incidence is 1.5%, approximately two-thirds are predominantly venous, and they are evenly distributed according to sex and race. Unlike hemangiomas, vascular malformations do not have a growth cycle and subsequent spontaneous regression but rather persist throughout the person's lifetime, growing slowly, sometimes in response to injury, changes in blood or lymph pressure, infections, hormonal changes, etc. Characteristically, these lesions progressively produce ectasia of vascular structures, increasing the diameter of vessels without increasing their number. Expansion is therefore by hypertrophy but not by hyperplasia, as is the case for hemangiomas.

Venular malformations can be divided into midline malformations and traditional venular malformations known as port wine stains, telangiectatic nevus, or nevus flammeus.

Midline lesions are pink macules that may or may not be confluent, are always present from birth, and appear on the midline of the head. They are usually transient and tend to disappear during the first year of life in 65% of boys and 54% of girls, particularly in case of lesions on anterior sites. Unlike port wine stains, they never progress, and hypertrophy or cobblestone appearance is extremely uncommon.

Port wine stains (PWS) are reddish-pink macules that darken over time. Although they are always congenital, they do not become visible until several days after birth. They occur in 0.4% of new-

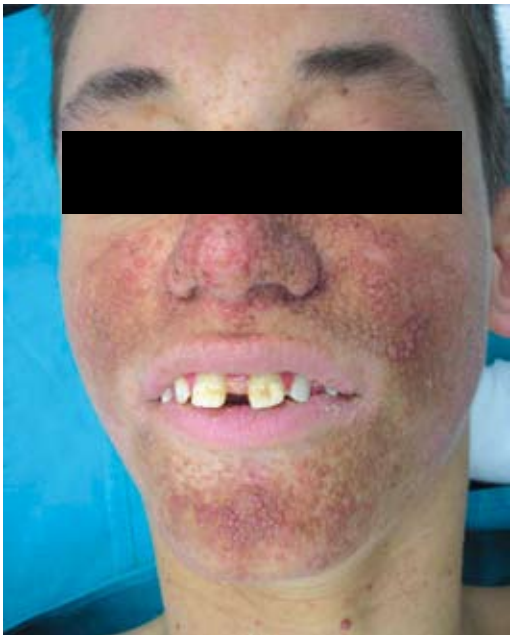

Figure 5. Facial angiokeratosis.

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borns and equally in boys and girls. In 83% of cases, they appear on the head and neck and they affect the right side of the face more often than the left side. Port wine stains are located on one or more facial dermatomes defined by branches of the trigeminal nerve. To explain the etiology of port wine stains, the term "sick dermatome" has been coined, whereby the lesion is due to completely or partly defective sensory and autonomic vascular innervation giving rise to growth of the affected vessels, which may even take on a cobblestone appearance (Fig. 4).

Telangiectases are prominent superficial capillaries that may occur at any site. Although the majority of telangiectases are isolated, lesions may be a heralding sign of underlying disorders (Fig. 5).

CLINICAL EXPERIENCES WITH PDL THERAPY

Prior to PDL application

Prior to formal laser therapy, a test patch should be considered. Such patients are seen in 2 to 3 months to be evaluated for response to therapy. During each application, overlapping of pulses (25% to 30%) is done with PDL. Immediate purpura, at least transiently, at treated sites is desired with PDL and indicates appropriate laser energy settings (34).

The majority of children may successfully complete office-based laser therapy *via* use of simple, topical anesthetics. Topical anesthesia in our hospital is typically achieved with EMLA, AstraZeneca LP, Wilmington, DE (2.5% lidocaine and 2.5% prilocaine) cream application 30 to 45 minutes prior to laser use. In addition, cold gels, ice-cubes or an air-cooling unit can effectively cool the epidermis to reduce local discomfort and minimize epidermal injury. Whereas older children can often tolerate laser therapy with topical anesthesia, very young patients or those with extensive lesions may require general anesthesia.

Hemangiomas: the goals of management are to prevent or avoid life- or function-threatening complications, to prevent permanent disfigurement, to minimize the psychological impact on the patient and parents, to avoid aggressive or scarring treatments, and to avoid/treat ulceration to minimize pain or scarring (35).

The selection of optimal laser therapy for hemangiomas depends strongly on the evolutionary stage of the lesion (36-44). Early lesions or those late in the evolutionary phase tend to respond better to such treatment.

Treatment parameters of pulsed dye lasers are generally 585 nm, 0.5 ms-1.5 ms, 5 to 7 J/cm^2 with epidermal cooling (39-49). For proliferating lesions, treatments are spaced at 2-3 week intervals, and at 4-6 weeks for nonproliferative lesions. The PDL, however, is limited by its depth of penetration, and is ineffective on deep hemangiomas (39-48).

PWS: After PDL treatment, about 65% of patients achieve between 50% and 90% lightening and 15% achieve greater than 90% lightening of their lesions with individual treatment sessions spaced 2 to 3 months apart; 8 to 10 serial treatments are often needed to achieve significant lightening of lesions (50-52). Superficial and postregression ***telangiectases*** need PDL therapy once to twice for full resolution (Fig. 6a and 6b).

With an incidence of less than 1%, the potential side effects of PDL treatment include ulceration with scarring and hypopigmentation that becomes more evident with further regression.

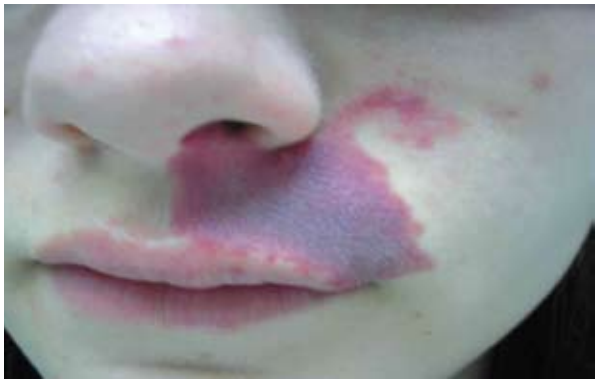

Figure 6. (a) Port wine stain before pulsed dye laser treatment;

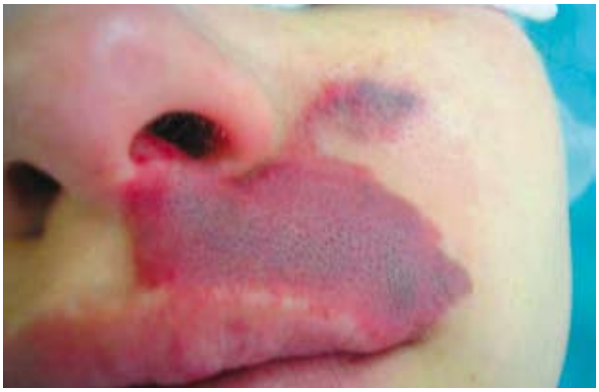

Figure 6. (b) port wine stain immediately after pulsed dye laser treatment.

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POSTPROCEDURE CARE

After PDL treatment, local ecchymoses, swelling and discomfort can occur. Application of cooling gel, ice packs, and NSA medications will minimize discomfort. Local erythema or purpura may persist for 7 to 14 days, sometimes followed by hyperpigmentation or hypopigmentation and atrophic scarring. Creams with high SPF should be used for protection as well as emollients until clearing of the purpura. PDL therapy can be repeated at 8-12 week intervals, and several treatments are very frequently required.

CONCLUSION

Laser therapy has become indispensable in the management of vascular birthmarks. In selecting a proper balance of wavelength, energy density, and pulse duration, laser energy can be molded to effectively manage many vascular lesions. Although no standard preprocedure study accurately characterizes all the parameters of target lesions, several imaging modalities continue to progress. In development, video-microscopy, modulated imaging, cross-polarizing diffuse reflectance imaging, and laser speckle imaging are expected to have widespread clinical effect on vascular lesions in the years to come (31). Factors such as deep dermal vessel location, presence of shielding cluster vessels, or inadequate energy deposition due to too little intravascular mass continue to limit effective therapy. Advances in intralesional energy release or future applications that enhance deep penetration yet limit collateral damage may one day provide answers to current clinical dilemmas (5).

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