Chapter 3
Vascular lesions

Vascular skin pathology is among the most common reasons for visiting aesthetic clinics, ranking third after hair removal and treatment for aging signs. This is due to three reasons:

1. Diversity of cutaneous vascular alterations
2. High frequency of occurrence
3. Proven high clinical effectiveness of laser technologies

The success of laser therapy in vascular lesions depends on various factors and, to a large extent, on the operator's skills. Physicians using vascular lasers must have the competence necessary to **correctly diagnose vascular skin lesions, explain the necessary nuances of treatment, assess the possible risks of therapy, select the parameters of laser exposure, and ensure safety during the procedure**.

3.1. Diagnosis

Vascular lesions can manifest as:

- **Vasodilation** (mainly capillary vasodilation), which leads to increased blood flow.
- **Capillary** constriction (vasoconstriction) and, consequently, a decrease in blood flow.
- **Violation of the vascular wall permeability**, which leads to impaired transport of substances from blood to tissues and vice versa, as well as to exudation of plasma and release of blood elements into dermal tissues (diapedesis).
- **Violation of vascular reactivity**, manifested by changes in mechanoreactivity (dermographism), thermoreactivity, neuro

reactivity, and hormonal reactivity, which may underlie the development of various pathological reactions to endogenous stimuli.

The localization of vascular lesions is very diverse in depth (**Table II-3-1**) and area — from limited foci (sometimes very small within one microcirculatory unit) to diffuse and even generalized, occupying significant areas or almost the entire skin.

Table II-3-1. Location of different types of skin vascular pathology

LEVEL	PATHOLOGY	DEPTH, μm
Subepidermal	• Superficial telangiectasias (TAE) in photoaging • Erythema in inflammatory skin diseases • Capillary angiodysplasia (CAD), also known as port-wine stain • Neovasculogenesis in scarring • Atrophodermia	40–50 70–260
Dermal	• Deep secondary TAE in severe photoaging • Age-related TAE • TAE in rosacea • TAE in collagenosis • Vasculitis • CAD • Cherry and spider angiomas	460–2235
Subdermal	• Venulectasias (blue reticular vessels 1–3 mm in diameter) • Angiomas and hemangiomas • Arteriovenous malformations • Venous malformations	1560–4000
Subcutaneous	• Hemangiomas • Arteriovenous malformations • Venous malformations • Reticular varicose • Saphenous veins pathologies	1800–4750 and deeper

It is essential to realize that correct diagnosis is the basis for successful therapy. A significant number of patients with vascular birthmarks receive ineffective and potentially dangerous treatment based on an incorrect diagnosis. To determine the exact nature of the vascular pathology, a detailed history and a thorough patient examination are necessary (Gloviczki P. et al., 2023).

According to the Grading of Recommendations, Assessment, Development and Evaluation (GRADE), most congenital and acquired vascular skin lesions belong to **class 1A** laser therapy. Class 1A recommendations are "strong" and have a meaningful evidence base. They should apply to most patients. Clinicians should only disregard these recommendations if a clear and convincing rationale exists for an alternative approach.

Currently, laser therapy can be used for the following vascular defects:

1. **Vascular malformations:**
   - Congenital vascular tumors (various forms of infantile hemangiomas, congenital hemangiomas, pyogenic granuloma, angiokeratoma)
   - Vascular malformations: port-wine stains — both as a separate pathology and associated with other anomalies (Sturge–Weber syndrome, Klippel–Trenaunay syndrome, etc.), telangiectasia (TAE), nevus simplex, venous malformations
2. **Acquired vascular lesions of the skin:**
   - Facial TAE
   - Rosacea
   - Spider angioma
   - Venous angioma
   - Cherry angioma
   - Senile angioma
   - Poikiloderma of Civatte
   - Pyogenic granuloma
   - Angiofibroma
   - Skin lesions in Kaposi's sarcoma
   - TAE of the lower extremities
   - Red and hypertrophic scars
   - Viral warts

- "Fresh" red stretch marks
- Inflammatory linear verrucous epidermal nevus
- Acne
- Psoriasis

Lasers are not recommended for treating arterial malformations because of the low evidence base (**class 1C**).

3.2. How do vascular lasers and IPL work

The target in treating vascular pathology is red blood cell hemoglobin, located in numerous dilated dermal vessels. Upon absorbing laser radiation, hemoglobin heats up and heats the vessel walls, which leads to their coagulation (photothermal effect) or rupture (photomechanical effect) (Zhang C. et al., 2023).

- **The photomechanical effect** manifests when a large amount of energy is transferred to the chromophore quickly. A so-called photodynamic shock occurs, the vessel ruptures and its contents are released into the tissue, leading to the formation of purpura, petechiae, and hemangiomas.
- **The photothermal effect** occurs with slower heating of the target (longer pulse) with gradual adhesion (coagulation) of the vessel. Blood, subjected to photocoagulation, forms a thermal coagulum — an amorphous accumulation of damaged and agglutinated erythrocytes and plasma components that clog the vascular lumen. Histologically, selective vessel damage with thrombosis, necrosis of the vessel wall, and perivascular collagen damage with relatively little thermal damage to the epidermis and dermis are noted.

Since IPL devices emit a broad range of wavelengths absorbed by different skin chromophores, most of this energy is absorbed by superficial targets such as pigment and dilated vessels. Higher energy parameters must be used to heat deeper targets, which increases the risk of burns and other complications, such as hyper- and hypopigmentation, and scarring (Sheptii O.V., 2018).

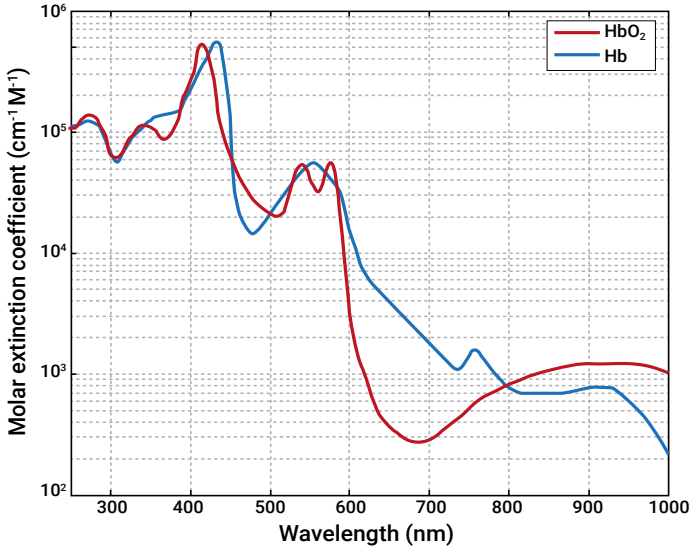

Figure II-3-1. Absorption curves of oxyhemoglobin (HbO_2) and deoxyhemoglobin (Hb)

3.3. Important parameters of vascular lasers

Wavelength

Regardless of the type of vascular lesions (arterial, venous, or capillary origin), hemoglobin remains the primary target for laser treatment (**Fig. II-3-1**):

- In small superficial vessels (mainly on the face and neck), the target is **oxyhemoglobin**, which has a maximum absorption peaks at 542 nm and 577 nm.
- In vessels on the legs, which are usually deeper and contain more **deoxyhemoglobin**, light of 800–1200 nm is used.
- In postcapillary venous malformations such as port-wine stains, 630–780-nm light is adopted.

The longer the wavelength, the deeper the radiation penetrates the skin (**Fig. II-3-2**). For example, Nd:YAG radiation of 1064 nm can penetrate several millimeters below the epidermis. **Longer wavelength light "bypasses" epidermal melanin, making it relatively safe for**

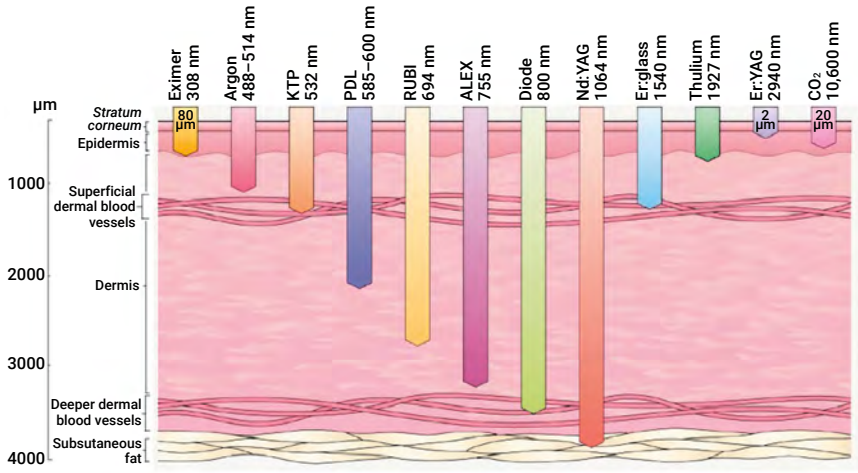

Figure II-3-2. Depth of penetration of lasers radiation (Image adapted from Plsatic Surgery Key)

darker skin types. However, coagulation of a deep vessel requires a much higher radiation energy density.

Infrared radiation treats deeper "blue" vessels more effectively, while shorter-wavelength light is more effective for superficial "red" telangiectasias.

Pulse duration

As noted previously, the effective and safe pulse duration for removing specific targets is determined based on the **thermal relaxation time (TRT)**. In vascular lesions, our target is not the hemoglobin itself but the vessel wall. According to the enhanced selective photothermolysis, hemoglobin is used as a target for heating with the expectation that the heat generated will be sufficient to damage the vascular wall. Therefore, pulse duration should be determined based on the blood flow volume and vessel diameter (**Table II-3-2**).

Table II-3-2. Thermal relaxation time of different skin structures

TARGET	SIZE, μm	TRT, ms
Melanosoma	0.1–0.5	0.25
Hair follicle	200	18
Vessels	50	1.2
	100	4.8
	200	19
	300	42.6
	400	160

For estimating the blood flow, the following parameters should be considered: the erythrocyte diameter is 7–10 μm, the average diameter of a capillary is 5–10 μm, and the blood flow velocity is 0.5–1 mm/s. Each blood particle is within the capillary for approximately one second. Thus, there may be only one erythrocyte in the lumen of malformed capillaries. As it moves slowly, its hemoglobin just transfers the energy that will lead to thermolysis of the vascular wall (coagulation or rupture depending on the pulse duration). Blood velocity in arterioles is 3 mm/s, while it is lower in venules — about 0.7 mm/s (due to lower pressure). Venules also have a significantly larger diameter than capillaries. In larger vessels, there are many red blood cells, and their speed is greater, so such vessels are much more difficult to remove. In this case, a different pulse duration should be used, and a large spot size may help.

Pulse frequency

Overlapping pulses or high pulse rates can result in thermal damage to tissue. However, in certain situations and in the hands of an experienced practitioner, this technique can yield good results — accumulated pulses with lower energy density can produce effects like a single higher-energy density pulse (IPL) on the target. For example, treating superficial facial TEA using the "pulse accumulation" technique can improve clinical outcomes without significantly increasing the risk of adverse side effects.

Spot size

Blood is in continuous motion. Accordingly, we are dealing with a dynamic chromophore. A new portion of blood "takes up" the heat generated by the absorption of laser energy, protecting the vessel from overheating. Therefore, a larger spot size is recommended to increase the circulating blood heating rate. In addition, a larger spot size promotes deeper penetration of laser light into the skin at equal radiation parameters.

Cooling

We must deliver high-energy pulses to targets deep in the skin to treat vascular lesions while minimizing damage to keratinocytes and melanocytes. This is mainly achieved by cooling the epidermis using a cryogenic spray, chilled air jet, or sapphire contact tips.