Laser Treatment of Benign Cutaneous Vascular Lesions

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Benign cutaneous vascular lesions have been treated with a wide array of modalities. Lasers are a comparatively new form of treatment for cutaneous blood vessel abnormalities. Initially, results following laser treatment were disappointing, primarily because of widespread thermal injury to surrounding normal tissue. Recent developments in laser technology and the introduction of the tunable dye laser offer the ability to selectively target laser energy at specific chromophores such as oxyhemoglobin. The technique of selective photothermolysis provides successful treatment of benign vascular lesions with minimal damage to adjacent structures.

Although benign cutaneous vascular lesions such as hemangiomas and vascular malformations are rarely life-threatening, treatment is often sought when organ function is compromised or when the lesion darkens in color, bleeds or imposes a psychologic burden on the patient. Various treatments have been used to remove such lesions, including surgery, ionizing radiation, cryotherapy, sclerotherapy, tattooing with flesh-colored pigments, dermabrasion, electrocautery and intralesional or systemic steroids.

Scarring has been associated with most, if not all, of these treatments. Each modality also carries specific potential disadvantages. Surgery is associated with the possibility of postoperative complications such as infection and hemorrhage. Complications of radiation therapy include skin necrosis, epiphyseal damage, cataracts, breast hypoplasia, lymphoma, thyroid and testicular carcinoma, and other malignancies. In spite of serious systemic side effects, high-dose intralesional or systemic steroids have been successfully used to treat certain rapidly enlarging hemangiomas that threaten vital organs such as the eyes. Until the introduction of lasers, the limitations imposed by these different therapies often made cosmetic camouflage with opaque makeup, such as Covermark® and Dermablend®, the only safe and acceptable treatment.

Lasers have been used in the treatment of benign cutaneous vascular lesions since the mid-1960s. A ruby laser, with emission in the red wavelength at 694 nm, was the first laser used to eradicate lesions such as port-wine stains. Because of the relatively low absorption advantage of hemoglobin at this wavelength (Figure 1), the ruby laser lacks vascular specificity, and nonspecific thermal injury of the irradiated site results.

![Absorption spectrum of oxyhemoglobin, hemoglobin and melanin. Emission wavelengths of dye and argon lasers.](image-url)
The ruby laser was soon replaced by the argon laser, which has wavelengths in the blue and green spectrum (488 nm), providing a fair degree of selectivity for a vascular target\textsuperscript{13-16} (Figure 1). Although the results with the argon laser were good to excellent in 60 percent of patients, adverse effects such as scar formation remained a problem, especially in children.\textsuperscript{14,15}

Scar formation has been overcome, in part, by the pulsed dye laser. The wavelength of this laser is tuned to about 577 nm (to coincide with the third oxyhemoglobin absorption maximum), and its pulse duration (exposure time) is shortened to between 300 and 500 µsec.\textsuperscript{17} Vascular-specific injury occurs with this combination of laser exposure time and wavelength. The ability to therapeutically target injury reduces the incidence of adverse effects, particularly scar formation.\textsuperscript{18}

Classification of Vascular Birthmarks

Benign vascular lesions can be categorized into two types, congenital and non-congenital (Table 1). Classification of congenital vascular birthmarks has historically been confusing. The medical literature has been inundated by an assortment of terminologies, including hemangioma, nevus flammeus, "stork bites," port-wine stains. Hemangioma became the generic term used to describe a variety of acquired and congenital vascular lesions. Because this classification was broad, however, it led to confusion regarding prognosis.

CONGENITAL LESIONS

Classification of congenital vascular lesions is based on clinical and histological presentations of birthmarks (Table 1). Lesions that develop by undergoing an initial phase of rapid proliferation followed by cessation of growth and involuision are classified as hemangiomas. Vascular birthmarks that persist through the patient's lifetime and grow commensurately are classified as vascular malformations; this group includes port-wine stains (Tables 1 and 2).

Hemangiomas. Hemangiomas tend to be present at birth but appear during the first few days to weeks of life, often as single, small macules. These lesions grow rapidly, becoming red and raised. The lesions increase in size during the following weeks to months, until the child reaches about 12 months of age, when growth stops\textsuperscript{19} (Table 2).

The reported incidence of hemangiomas varies.\textsuperscript{20} The lower incidence of 1.1 to 2.6 percent was reported in a survey performed in a neonatal unit. Incidences between 8.7 and 10.1 percent have been documented in studies of two outpatient populations. The apparent discrepancy in the incidence found in these different studies is best explained by the fact that many lesions first appear after the newborn is discharged from the hospital. The reported female-to-male ratio varies from 1:1 to 3:1.\textsuperscript{19}

Hemangiomas occur most frequently...
Comparison of Hemangioma and Vascular Malformation

<table>
<thead>
<tr>
<th>Features</th>
<th>Hemangioma</th>
<th>Vascular malformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidence</td>
<td>1.1 to 10.1 per 1,000</td>
<td>3 per 1,000</td>
</tr>
<tr>
<td>Presentation at birth</td>
<td>30%</td>
<td>100%</td>
</tr>
<tr>
<td>Female-to-male ratio</td>
<td>1:1 to 3:1</td>
<td>1:1</td>
</tr>
<tr>
<td>Clinical course</td>
<td>Initial proliferation</td>
<td>Growth commensurate</td>
</tr>
<tr>
<td></td>
<td>followed by involution</td>
<td>with person</td>
</tr>
<tr>
<td>Histology</td>
<td>Increases in proliferative</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>phase; decreases in</td>
<td></td>
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<tr>
<td></td>
<td>involutionary phase</td>
<td></td>
</tr>
<tr>
<td>Endothelial cell numbers</td>
<td>Increases in proliferative</td>
<td>Normal</td>
</tr>
<tr>
<td>Mast cell numbers</td>
<td>phase; normal after</td>
<td></td>
</tr>
<tr>
<td>Basal membrane</td>
<td>involution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Multilaminated</td>
<td>Normal</td>
</tr>
</tbody>
</table>

on the face or neck and tend to vary in size from a few millimeters to many centimeters in diameter. The fully developed hemangioma is often dome-shaped, ranging in color from bright red to dark purple (Figure 2). The lesion becomes darker and more elevated with straining or crying.

Approximately 50 percent of hemangiomas spontaneously involute by the time the child is five years of age. Of those that persist, more than one-third resolve by the age of 10. Overall, the spontaneous involution rate is approximately 70 percent by age seven. The rate and degree of resolution appear not to be influenced by gender, gestational age, lesion size or depth, presence of ulceration, time of onset or site, except that lesions on the lip generally have less satisfactory final results. Hemangiomas that remain unchanged for three years are unlikely to resolve spontaneously.

Vascular Malformations. Vascular malformations, such as port-wine stains, differ both clinically and histologically from hemangiomas (Table 2). Vascular malformations are almost always present at birth and occur with equal frequency in males and females. The port-wine or red color of these lesions is a consequence of enlarged, ectatic blood vessels in the dermis, rather than an increase in the number of blood vessels.

The incidence of port-wine stains is estimated to be 0.3 percent; 80 to 95 percent are located on the head and neck. In a study of 106 cases of facial port-wine stains, 45 percent were restricted to one of the three trigeminal sensory areas. The remaining 55 percent crossed the midline, occurred bilaterally or involved adjacent dermatomes.

Most port-wine stains appear to involve only the skin; however, approximately 5 percent of patients with port-wine stains have concomitant leptomeningeal involvement (Sturge-Weber syndrome) and/or ocular involvement. One study has recently shown that children with port-wine stains of the upper and lower eyelids bilaterally are more likely to have associated leptomeningeal and/or ocular involvement. In this study, 24 percent of patients with bilateral port-wine stains involving the trigeminal distribution developed Sturge-Weber syndrome and/or glaucoma, compared with 6 percent of those with unilateral lesions.
At birth, port-wine stains appear as pale pink macules (Figure 3). They darken with age, becoming red to purple, and often develop small nodules within the birthmark, which give the lesions a studded appearance (Figure 4). In extensive lesions, hypertrophy of underlying soft tissues often occurs (Figure 5).

Histologic and ultrastructural studies have suggested that the deepening color and nodularity in older lesions represent progressive ectasia of the abnormal vascular plexus in the upper dermis and stagnation of blood flow within the ectatic vessels. A decrease in perivascular neangiogenesis in port-wine stains has been postulated as the factor responsible for progressive ectasia in these lesions.

NONCONGENITAL LESIONS

Telangiectasia. Telangiectasia make up the major group of noncongenital malignant vascular lesions. The term “telangiectasia” describes a superficial vessel in the skin that is visible. Individual telangiectasia measure 0.1 to 1 mm in diameter and represent an expanded venule, capillary or arteriole.

Redisch and Pelzer classified telangiectasia into four types, based on the clinical appearance: linear, arborizing, spider and papular.

Red linear telangiectasia occur commonly on the face, especially on the cheeks and nose (Figure 6). Blue arborizing telangiectasia are found most often on the legs (Figure 7). Spider telangiectasia have a central filling vessel of arteriolar origin (Figure 8). If pressure is exerted on the feeder vessel, the branching arm of the “spider” blanch. Papular telangiectasias are frequently part of such syndromes as Osler-Weber-Rendu disease or collagen vascular disease (CREST drome) (Figure 9). It has been suggested that excess estrogen might be respons...
for telangiectasias that arise in a variety of conditions, including anoxia, hepatic insufficiency or pregnancy.26

Principles of Laser Therapy

Lasers are currently used in almost every medical specialty and are playing an increasing role in dermatology. Laser has unique properties, including coherence, monochromaticity and high intensity of light beam, which separate it from conventional light sources. Within the laser beam, all photons (waves) of light are in phase and of a single wavelength, traveling in parallel. The laser beam travels in a straight line until its photons interact with matter in its path. A photon of laser light may be reflected (altered in direction) or absorbed (its energy taken up by a target molecule). Lasers can be used in dermatology to cut, ablate, coagulate and selectively destroy specific targets in the laser-exposed skin.
field (selective photothermolysis, or SPT). Laser-irradiated tissue can undergo specific or nonspecific injury. In nonspecific injury, all structures along the path of the laser beam are destroyed. The neodymium: yttrium-aluminum-garnet (Nd:YAG) laser at 1,060 nm is such an example, producing nonspecific tissue injury. The Nd:YAG laser is useful for thermal destruction of tissue in areas where no predominant chromophores exist. (A chromophore, or target molecule, is a substance within the tissue that is capable of absorbing energy, or photons, at a particular wavelength.)

By contrast, the laser can also be used to destroy specific chromophores within the laser-exposed field. The preferential absorption of laser energy by the targeted chromophore over its adjacent structures enables the laser to destroy specific targets, with minimal effect on surrounding tissues. For example, the two endogenous chromophores or pigmented structures in the skin are hemoglobin (red) or melanin (black), which can easily be differentiated from adjacent nonpigmented epidermal and dermal cells by their color. Therefore, if a pathologic lesion has an abundance of a given chromophore compared to the surrounding normal tissue, a laser can be used to induce chromophore-specific injury to destroy the lesion.

Despite the theoretic possibility of inducing target-specific injury, most laser therapies produce relatively nonspecific thermal tissue injury. For instance, the carbon dioxide (CO₂) laser induces widespread injury within the target; this is because its wavelength (10,600 nm) is readily absorbed by water, which is present in every living cell. Even the argon laser, which was first used in an attempt to induce specific localized vascular tissue destruction by using hemoglobin as a chromophore for its blue-green light (488 nm and 514 nm), has been found to be relatively nonspecific. Among several reasons for problems with specificity are competing absorption of energy by melanin and lengthy exposure time (from second to continuous wave), which permit heat diffusion from the site of absorption to surrounding skin. Specificity of laser injury can, therefore, only be achieved by the careful choice of wavelength, pulse duration and density. The wavelength should coincide with absorption spectral peak of the targeted chromophore within the tissue (for example, oxyhemoglobin at around 577 nm). Pulse duration should not exceed the tissue's thermal relaxation time (time required for the target structure to cool to half its peak temperature immediately following laser exposure), and dose or energy density delivered should control the degree of tissue injury.

Laser Therapy for Cutaneous Vascular Lesions

Several lasers have been used to treat benign cutaneous vascular lesions (Table 1). The relative success of CO₂, argon, KTP, Nd:YAG and ruby lasers in the treatment of these lesions has been limited by nonspecific destruction of dermal as well as...
TABLE 3
Lasers Used in the Treatment of Benign Cutaneous Vascular Lesions

<table>
<thead>
<tr>
<th>Laser type</th>
<th>Wavelength (nm)</th>
<th>Chromophore</th>
<th>Lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruby</td>
<td>694</td>
<td>Melanin</td>
<td>Vascular, pigmented, tattoos</td>
</tr>
<tr>
<td>Argon</td>
<td>488, 514</td>
<td>Hemoglobin</td>
<td>Vascular, pigmented</td>
</tr>
<tr>
<td>Dye</td>
<td>Variable (depends on dye)</td>
<td>Melanin</td>
<td></td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>1,060</td>
<td>Variable</td>
<td>Vascular</td>
</tr>
<tr>
<td>CO₂</td>
<td>10,600</td>
<td>Water</td>
<td>Warts, keloids, epidermal nevi</td>
</tr>
</tbody>
</table>

Nd:YAG = neodymium:yttrium aluminum garnet; CO₂ = carbon dioxide.

dermal structures. Although the pulsed dye laser also affects tissue by heat transfer, nonspecific injury of adjacent dermal tissue is minimized because the laser energy is preferentially absorbed by the target chromophore, oxyhemoglobin, at around 577 nm, and the injury is confined to blood vessels alone. Therefore, diffusion of the absorbed energy (heat) is minimal to surrounding structures such as dermal collagen. This type of localized injury has reduced the incidence of adverse effects, such as scarring.

HEMANGIOMAS

Fair to excellent results have been reported in the treatment of hemangiomas. Those hemangiomas requiring treatment (i.e., those compromising vital functions or eroding underlying architecture) have been successfully treated using the argon and Nd:YAG lasers and, more recently, the pulsed dye laser (585 nm). In most instances, clinical improvement has been manifested by the reduction or loss of surface vascularity, often accompanied by complete involution.

PORT-WINE STAINS

Port-wine stains were initially treated fairly successfully with the argon laser, but use of the argon laser was later found to be limited by scarring, which occurred most severely in patients younger than age 17. It was postulated that the poor response reported in children was the result of insufficient hemoglobin (the target chromophore in red blood cells) within the smaller blood vessels compared with an abundance of this chromophore in the more ectatic vessels present in mature, dark-red to purple lesions. Some investigators, however, believed that the scarring observed in children resulted from bacterial suprainfection of the treated tissue.

Other lasers used in the treatment of port-wine stains include the CO₂ and Nd:YAG lasers. The nonspecific thermal injury induced by both of these laser systems has limited their usefulness in the eradication of port-wine stains. More recently, the pulsed tunable dye laser (initially 577 nm; now, 585 nm) has been shown to be effective for port-wine stains, without subsequent scarring. The pulsed dye laser is now the laser of choice for the treatment of port-wine stains in children. Because injury induced by this laser is specifically localized to blood vessels alone, the pulsed dye laser can be used in children of any age, even as young as a few days old.

In addition to port-wine stains, other benign vascular lesions, such as telangiectasias, can be successfully removed with the pulsed dye laser.

REFERENCES

5. Hidano A, Ogihara Y. Cryotherapy with sol-