Laser Dermatology

Pearls and Problems

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The writing of any book requires hours of work, rework, and more work. This book could not have been written without the tireless efforts of my 2006 Procedural Dermatology fellow, Dr. Alexander L. Berlin. I cannot thank him enough.

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Contents

Foreword

Enthusiasm and knowledge only go so far. But industrious capitalization of these features can result in infectious and significant achievements with long lasting benefits. And so David Goldberg's excellent review of energy based systems entitled *Laser Dermatology: Pearls and Problems* is arriving at a most propitious time.

Not so long ago, there were only a few therapeutic lasers available and the choices were easy. It was all about how to use the continuous wave CO_2 laser in one of its three modes—cutting, vaporization, or coagulation—which all related to spot size and power. Or how to improve the appearance of port wine stains with the argon or copper vapor lasers without scarring the heck out of the patient. In retrospect, we used to do a pretty good job considering the lack of selectivity and low tissue tolerance for these devices. There were few "Problems" and even fewer in the way of "Pearls."

But now it's a different ball game. The varying different energy based devices (not just lasers) are numerous, more selective, safer, and in many cases less effective than we would like them to be. Problems can exist if they are not used appropriately. Pearls come through the experience of using such devices effectively. This book moves beyond laser and light based wavelengths, fluences and pulse durations and focuses on the wealth of experience of one of today's leaders in laser dermatology.

Dr. Goldberg should be congratulated for bringing together a very practical compilation of the pearls and problems in the current practice of laser dermatology. His well presented, organized series of concepts will be extremely useful for the experienced laser surgeon as well as the novice. Very evident in this book is the accuracy and honesty of the author. Laser dermatology is exciting. *Laser Dermatology: Pearls and Problems* is an essential read for all physicians interested in the nuances of this field.

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July 2007

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Preface

Laser Dermatology: Pearls and Problems is not meant to be just another book written about lasers in dermatology. There are plenty of such books already written on that topic – some by me. All other books dealing with this vast arena either focus on (a) the skin entities that can be treated with lasers; (b) the latest in dermatological lasers; or (c) complications that may induced by those lasers. Where this book is different is the manner in which it looks at lasers in dermatology. This book is divided into five chapters. Each chapter starts off by highlighting essential concepts. This is then followed by a focus on pearls and problems of five major areas of laser dermatology. In addition, the photographs contained within each of the chapters are meant to serve a different purpose than is seen with most textbooks. The focus of pictures in this book is not to present before and after photographs. Such a focus is contained in many outstanding textbooks. Although there are occasional before and after pictures contained within the text, the focus, in this book, is to use pictures to illustrate some of the many pearls and problems that can be seen in the realm of laser dermatology. Twenty years of laser dermatology have given me a chance to see the beauty of the "Pearls" and the difficulties of the "Problems" in Laser Dermatology. Enjoy!

David J. Goldberg, MD, JD
March 2007

Vascular Lasers

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Vascular Lasers

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KEY POINTS

- The pulsed dye laser, originally only used in a purpuric mode, is now highly successful without the induction of purpura for the treatment of most vascular lesions
- Pulsed dye lasers used for the treatment of port-wine stains lead to the best results when the clinical endpoint is purpura
- Facial erythema can be treated equally well with both pulsed dye laser and intense pulsed light treatment
- Twenty years after pulsed dye laser treatment of port-wine stains was initiated, the exact number of treatments remains an enigma
- Some leg spider veins can be treated with laser treatment; sclerotherapy remains the gold standard

Introduction

Cutaneous vascular lesions, especially those occurring on visible sites, such as the face, may cause significant psychological distress. This is true not only of port-wine stains (PWS), whose detrimental effect on patient is well recognized [1,2], but also of other vascular malformations, proliferations, and ectasias. Frequently, however, the latter conditions tend to be underdiagnosed and undertreated. The introduction of compact and more affordable lasers, being used in an outpatient setting, allowed for easier patient access with more reliable and cosmetically pleasing results.

The treatment of vascular lesions is one of the most commonly requested cutaneous laser procedures. Since the introduction of the argon laser, a variety of lasers and light sources have been used in the treatment of vascular lesions. These include visible and infrared lasers, as well as broadband light sources. Despite some limitations, lasers and light source devices remain the modality of choice for a variety of vascular lesions.

Essential Concepts

Vascular Laser Biology, Chromophores, and Tissue Targets

A large variety of vascular-specific lasers and light-based devices have been developed over the years. All of the systems currently in use are based on the principles of selective photothermolysis introduced by Anderson and Parrish [3]. Photons of light produced by lasers are absorbed by tissue chromophores within a specific target of interest, producing heat. The heat is dissipated through conduction; therefore, if sufficient energy is delivered faster than the rate of cooling, heat accumulates within the target and selectively destroys it.

Tissue absorption and scattering determine penetration of laser light into the skin. Collagen is the major cause of scattering, which decreases as the wavelength of light increases. Therefore, longer wavelengths can penetrate deeper into the skin and, subsequently, the choice of a specific laser will depend on the depth of the desired tissue target. As the wavelength is increased into the far-infrared region, light begins to be heavily absorbed by water, which limits its penetration.

Oxyhemoglobin and, to a lesser extent, deoxyhemoglobin are the main chromophores for vascular lasers. The major absorption peaks of oxyhemoglobin are 418 nm (blue), 542 nm (green), and 577 nm (yellow) [4]. The largest peak is at 418 nm; however, this wavelength does not allow adequate penetration into the skin. The other two peaks, as well as a broad absorption band between 800 and 1100 nm form the basis for vascular lasers in use today.

The patient's Fitzpatrick skin type is important when considering a vascular laser, as melanin may compete with oxyhemoglobin for light absorption, potentially resulting in dyschromia. Melanin absorbs mainly in the ultraviolet and the visible light spectrum, with decreasing absorption in the near-infrared region of the spectrum. Therefore, longer wavelengths are better used in patients with Fitzpatrick types IV to V to minimize the risk of dyspigmentation.

Laser Settings: Pulse Duration, Spot Size, Fluence, and Cooling Methods

Heat is transferred from erythrocytes containing the hemoglobin to the surrounding endothelial cells, causing damage to the blood vessel wall. If light is pulsed with exposure time less than or equal to the thermal relaxation time (TRT), heat is maximally confined to the target – in this case, the blood vessel wall.

TRT is directly proportional to the square of the size of the object and inversely proportional to thermal diffusivity, an intrinsic property of a material to diffuse heat [3]. Thus, as the blood vessel diameter is doubled, the cooling time increases fourfold. A useful quick approximation of TRT, in seconds, is the square of the target size in millimeters [5]. Additional considerations in determination of TRT for larger targets, such as large-caliber vessels of the legs, will be discussed in a later section.

Once the TRT is determined, an appropriate pulse duration, also known as the pulse width, is selected to match the target blood vessel diameter. As an example, the TRT of capillaries is in the order of tens of microseconds, that of venules is in the hundreds of microseconds, whereas in adult PWS, the TRT is between 1 and 10 ms [6]. As the delivered pulse duration surpasses the TRT of smaller blood vessels, sufficient heat diffusion is afforded, allowing for the preferential treatment of larger-caliber vessels [3]. It is thus crucial to know the specific structure and composition of the vascular lesion to be treated [7].

The theory of selective photothermolysis requires sufficient fluence, also known as energy density, to reach a damaging temperature within the target – approximately 70°C for blood vessels [3]. Precise choice of fluence is important, as excessive fluences may result in increased incidence of adverse effects, such as scarring and dyspigmentation.

Laser beam diameter, or spot size, also influences the choice of fluence. Compared to a smaller spot size, a larger spot size results in a smaller percentage of light being scattered outside the actual delivery of light, with subsequent delivery of greater amount of energy and greater damage to the deeper dermal target. Consequently, with all other factors being equal, lower fluences can be used with larger spot sizes [8]. In addition to the depth of the target, the choice of spot sizes is also influenced by the overall size of treated lesion. The largest spot size accommodated by the treatment area is typically selected, with small spot sizes usually reserved for isolated small superficial blood vessels.

Absorption of light energy, by competing epidermal melanin, and retrograde conducted heat from the actual treated dermal target may result in undesired epidermal damage. This may eventuate in blistering, dyspigmentation, and scarring. Epidermal cooling is employed to minimize the risk of such undesired damage. Cooling allows for higher fluences to be used, thus enhancing treatment efficacy [9]. Localized cooling also has an additional benefit of providing local anesthesia and reducing swelling, making the treatment more tolerable to the patient. Epidermal cooling can be achieved through contact, including ice packs, cold gel, and sapphire window; cold air convection; or automated liquid cryogen spraying immediately prior to laser pulse, a process known as dynamic cooling [9].

Classification of Vascular Lesions

The composition and structure of the vascular lesion, as well as its natural history, need to be ascertained prior to treatment. Such assessment will allow the proper selection of the appropriate vascular laser and laser settings. In some instances, varying composition within the same lesion will require changes in laser parameters or a decision to use multiple separate lasers. In other instances, such as some hemangiomas of infancy, laser therapy may not always be appropriate and may be reserved for very early or for complicated cases.

With continuing expansion of clinical indications for vascular lasers, a proper classification system is important. The most useful classification system is based on endothelial characteristics. Thus, congenital vascular lesions can be subdivided into (1) hemangiomas, with endothelial cell hyperplasia, and (2) vascular malformations, with normal endothelial cell turnover and variable degree of vessel ectasia [10]. Most acquired vascular lesions, such as telangiectasias, spider and cherry angiomas, venous lakes, pyogenic granulomas, and leg vein abnormalities, are characterized by vessel ectasia.

PWS are the most common type of congenital vascular malformation. They represent low-flow capillary malformations, are present at birth, and most commonly occur on the face and neck. They may also be part of several rare conditions, such as Sturge–Weber and Klippel–Trenaunay syndromes. PWS increase in size, proportionally to the growth of the child, and never involute. As the degree of vascular ectasia increases over time, the lesion becomes darker and frequently develops hypertrophy and nodularity in adulthood. Histologically, an abnormal papillary dermal plexus of ectatic vessels varying in size between 10 and 300 μm underlies a normal epidermis at the depth of 0.1 to 1 mm [11]. Such variability, within the same lesion, may make laser treatment that much more difficult.

Hemangiomas of infancy most often appear after the first few weeks of life, although a white or pink macule may sometimes be discerned prior to the onset of actual hemangiomas growth. Following the initial presentation, hemangiomas grow at a much faster rates when compared to the rest of the body

[10]. Depending on the location of the lesion, such rapid growth may at times impinge on the larynx, trachea, or eyes, endangering breathing or vision. Ulceration may also occur and may result in bleeding, pain, infection, and scarring. Hemangiomas may be subdivided based on the depth in tissue into three categories: superficial, appearing as bright red plaques; deep, appearing as bluish subcutaneous nodules; and combined or mixed [12]. Multiple or extensive hemangiomas also occur and may be segmental or diffuse, sometimes with visceral involvement. Most hemangiomas begin to involute after 12 to 15 months of growth, a process that may take up to 10 years. Following involution, residual epidermal atrophy with telangiectasias and fibro-fatty tissue may persist [13]. It is also important to recognize a recently described rare hemangioma variants, such as the non-involuting congenital hemangioma (NICH) and the rapidly involuting congenital hemangioma (RICH). The prognosis for these lesions is different from the conventional hemangioma of infancy [14].

Pearls and Problems

PWS: Pulsed Dye Laser

The pulsed dye laser (PDL) is generally considered to be the gold standard in the treatment of PWS (Figure 1.1). This laser has undergone several modifications since its original inception in an attempt to allow the laser to penetrate deeper into the dermis, to target deeper and larger vessels, and to better protect the epidermis, especially in darker skin.

Several factors, including the patient's age and Fitzpatrick skin type, anatomical location, size, composition, and color,

Figure 1.1 PWS ideally treated with the PDL.

influence the response of the PWS to the PDL. Of the head and neck lesions, those that are centrofacial, or dermatomal in the V2 distribution, are slower to respond to laser treatment [15]. PWS located on the extremities, and especially on distal extremities, respond more slowly than those on the trunk [16]. Smaller lesions respond better, with a 67% decrease in post-laser treatment size for those under 20 cm^2 compared to a 23% decrease in those over 40 cm^2 [17]. Ectasia, within ring-like vessels in the superficial horizontal plexus, as demonstrated by videomicroscopy, respond better to laser treatment, than those within capillary loops [18]. While application of this finding is difficult in clinical practice, it may explain some of the cases of differential response to treatment using identical laser parameters. Red color indicates more superficially located vessels and portends a better treatment prognosis. Purple color is attained by deeper-located larger-caliber vessels, whose response to treatment is intermediate, while that of pink lesions, with deep smaller-caliber vessels, is poor [19,20]. Early treatment of PWS has been shown to have better outcome [21,22], although this point remains somewhat controversial [23]. In general, fewer treatments are required, and better clearance can be achieved, in children less than 10 years old. Those PWS patients in whom therapy is started before 2 years of age potentially getting the best results [24,25].

After the above factors are analyzed through physical examination, realistic expectations have to be discussed with the patient or the parents. Such a discussion includes the number of required treatments, potential adverse effects, and the possibility of lightening rather than complete clearance of the PWS. Digital photographs prior to, and following treatments, are important to document gradual improvement.

Anesthetic requirements should also be considered prior to treatment. Cooling techniques, especially cryogen spraying, have made laser treatments tolerable for most adults. Topical anesthetics may be used, but may also cause vasoconstriction and render treatments less effective. Children may require conscious sedation or general anesthesia, especially when large lesions are being treated. Such techniques should be performed by a trained anesthesiologist and care must be taken to avoid any oxygen escape following intubation, as laser ignition of the oxygen may occur.

Generally, when using a 585-nm PDL, treatment of a PWS in a child, treatment is initiated at 6 to 8 J/cm^2, which may then be increased by 0.5 to 1 J/cm^2 at subsequent visits, if tolerated without adverse effects. Alternatively, several test spots using incremental fluences can be performed in the least obvious