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### Authors

Stuart Nelson, J  
Applebaum, Jay

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# Clinical Management of Port-Wine Stain in Infants and Young Children Using the Flashlamp-Pulsed Dye Laser

J. Stuart Nelson, M.D., Ph.D.\*, Jay Applebaum, M.D.†

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The flashlamp-pulsed dye laser (FLPDL) at 585 nm, a wavelength well absorbed by oxyhemoglobin, causes highly selective vascular injury. In addition, the 450 microsecond pulse duration produced by this laser approximates the thermal relaxation time for dermal blood vessels thereby confining the energy to the target.

This new laser effects excellent lightening of port-wine stain (PWS) in infants and young children without the adverse complications of hypertrophic scarring, permanent pigmentation abnormality, or textural changes, complications often seen with conventional laser systems. The FLPDL now permits treatment of this patient population expected to gain the most benefit from early laser therapy in a much safer manner, before the psychological complications of being a "marked" person develop.

The purpose of this report is to: (1) describe the theoretical considerations behind achieving selective removal of PWS that can be understood and used by a nonsurgically-oriented practitioner; and (2) describe the practical application of the device used in the clinical management of infants and young children.

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## Introduction

Port-wine stain (PWS) is a congenital vasculopathy that occurs in an estimated three infants per 1000 live births. It presents most commonly on the face and neck, but may be found anywhere on the body as an isolated finding or in association with systemic syndromes.<sup>1</sup>

In infants PWS is classically flat, salmon-colored, smooth surfaced and frequently follows the distribution of one

branch of the trigeminal nerve. Biopsies of PWS from infants show an abnormal network of ectatic vessels in the immediate subepidermal dermis with a normal overlying epidermis. With time there is progressive ectasia while the number of vessels stays constant. With this progressive dilatation, as the child ages, the color of the lesion darkens from pink to red to purple, and the skin surface becomes progressively more irregular, often taking on a "cobblestone" appearance with large vascular nodules.<sup>2</sup>

PWS has been treated in the past with an array of therapeutic modalities including skin grafting, ionizing radiation, dermabrasion, cryosurgery, tattooing and electrotherapy. All of these have met with limited success and have often left cosmetically unacceptable secondary scarring.

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\* Beckman Laser Institute and Medical Clinic, Irvine, CA. † Departments of Surgery and Dermatology, University of California, Irvine, CA.

Correspondence to: J. Stuart Nelson, M.D., Ph.D., Associate Director, Beckman Laser Institute and Medical Clinic, 1002 Health Sciences Road East, Irvine, CA 92715.

The introduction of the argon laser in the early 1970s represented the first major advance in therapy for PWS. The blue-green light (488, 514 nm) produced by this laser passes through the epidermis and is then preferentially absorbed by oxyhemoglobin ( $\text{HbO}_2$ ) in the dilated ectatic vessels in the upper dermis. There, the photon energy is converted to heat, causing thermal damage and thrombosis in the targeted vessels.<sup>3-6</sup>

Unfortunately, after initial enthusiasm, the mechanism of action described above was found to be overly simplistic in that the epidermis is not totally spared (due to undesired absorption of energy therein by melanin and other dermal components, including collagen, and to dissipation of heat from the injured vessels) and suffers some irreversible damage. Histopathology shows nonspecific coagulation necrosis of the epidermis and upper dermis to a depth of 1 mm in the acute phase with subsequent replacement by a diffuse collagenous deposit. With time, dermal scarring is seen. It is unknown what are the relative contributions to PWS lightening caused by (a) selective absorption of heat energy by  $\text{HbO}_2$  in the targeting vessels leading to direct vascular damage; and (b) relatively nonspecific absorption of light energy by surrounding tissues with secondary compression of the vessels. Suffice to say, argon laser therapy results in a controlled dermal scar with smaller vessels that have fewer red blood cells. Subsequently, lightening and smoothening of the involved skin also result. Clinical studies are encouraging but hypertrophic scarring, which occurs in up to 10-15% of children, remains a worrisome complication even in the hands of the most skilled practitioner. Hypertrophic scarring is particularly likely in the population expected to gain the most benefit from the laser therapy—young infants and children—due to the propensity for scar formation in younger age groups, particularly in the lips and perialar regions similar to that seen in children following thermal burn injury.<sup>7-9</sup> Argon laser therapy is therefore, not recommended for children younger than 18 years of age.

Continued improvement in treatment results, with reduction in scarring, will depend upon the ability to use lasers to induce selective injury of only the abnormal blood vessels in the dermis while sparing the normal overlying epidermis. Recent increases in our understanding of the optical characteristics of skin have made it possible to concentrate not only on the effects of any particular laser system but on the basic biological and physical principles of laser-tissue interaction.

If the clinical objective is to cause selective destruction of dermal blood vessels, the wavelength chosen should match a high absorption by the targeted  $\text{HbO}_2$  molecule

relative to other optically absorbing molecules. Choice of wavelength also determines the depth to which the optical radiation will penetrate with sufficient energy density to effect tissue change. The wavelengths suitable for consideration are the  $\text{HbO}_2$  Soret absorption band at 418 nm and the absorption bands at 542 and 577 nm. Despite the higher extinction coefficient of the Soret band, this wavelength can be rejected for clinical use on the basis that penetration of these photons into the dermis is insufficient to produce blanching of vessels deeper than 0.1 mm from the surface. Furthermore, absorption by melanin is higher at this wavelength leading to nonspecific thermal injury of the epidermis. However, if one can take advantage of the longer wavelength  $\text{HbO}_2$  absorption band at 577 nm where tissue penetration and melanin absorption is reduced, less heating of the epidermis should occur and more incident light energy will be transmitted to the blood vessels. Also, the extinction coefficient for  $\text{HbO}_2$  is higher at this longer wavelength than at the blue-green (488, 514 nm) wavelengths produced by the argon laser.<sup>10</sup> Newer laser systems now employ a wavelength of 585 nm based on a recent study which demonstrated that a greater depth of penetration can be achieved (1.20 mm at 585 as opposed to 0.50 mm at 577) at this longer wavelength while maintaining almost the same degree of specificity of vascular and perivascular injury to those previously described after exposure to 577 nm irradiation.<sup>11</sup>

In addition, optical factors such as wavelength and tissue factors such as absorption and penetration are not the only criteria for successful laser therapy. Given that one goal of treatment is the precise control of thermal energy, equally as important as optical and tissue factors in the pulse duration of laser irradiation. One way to maximize the spatial confinement of heat is to use a short pulsed laser with a pulse duration on the order of the thermal relaxation time of the tissue. The latter constant is defined as the time required for the heat generated by the absorbed light energy within the target chromophore to decrease to 50% of its initial value immediately after exposure to the laser. Longer pulse durations offer a more generalized heating, and therefore, less spatial selectivity resulting in nonspecific thermal damage to adjacent structures regardless of how carefully one has chosen a wavelength since the absorbed energy is invested almost uniformly in heating of the tissue during exposure, despite its origin in the target structure. However, if the laser pulse is suitably brief, its energy is invested in the target chromophore before much heat is lost by thermal diffusion out of the exposure field. Shorter pulse durations confine the laser energy to progressively smaller targets with more

spatial selectivity. A maximum, transient temperature between the target and adjacent structures will then be achieved. The calculated thermal relaxation time for dermal blood vessels, typical of PWS in children, is 190 micro-to 3 milliseconds.<sup>12,13</sup> In commonly available argon lasers, the shortest available pulse duration is 0.05 second which accounts for the non-specific damage produced by these devices.

The flashlamp-pulsed dye laser (FLPDL) at 585 nm, a wavelength well absorbed by the targeted oxyhemoglobin ( $\text{HbO}_2$ ) molecule relative to other optically absorbing structures, causes selective thermal damage to dermal blood vessels while minimizing the epidermal melanin absorption. Furthermore, the 450 microsecond pulse duration produced by this laser closely matches the thermal relaxation time for dermal blood vessels thereby confining the laser energy to the targeted  $\text{HbO}_2$  molecule before much heat is lost by thermal diffusion out of the exposure field. If used correctly, the FLPDL laser can cause selective destruction of cutaneous vascular lesions with no clinical evidence of hypertrophic scarring, atrophy, induration or hypopigmentation, complications seen with the argon,  $\text{CO}_2$  or Nd:YAG laser.

### Clinical Management

Irradiations are performed with a SPTL-1 flashlamp-pulsed dye laser (Candela Laser Corp., Weyland, MA). High-intensity flashlamps excite the dye directly to produce visible photons at a wavelength of 585 nm. The laser is capable of producing a 450 microsecond pulse at a maximum energy density of  $10 \text{ J/cm}^2$ . Energy densities typically used for treatment of lesions in infants and young children range from  $4.5\text{--}6.5 \text{ J/cm}^2$  and are calibrated with an energy meter. Laser energy is focused into a 1 mm core diameter quartz optical fiber which terminates in a microlens that focuses the laser radiation on a 5 mm circular spot of uniform light intensity. All personnel and the patients must wear safety glasses that absorb specifically at the wavelength being used, to prevent inadvertent eye damage during the laser treatment.

### Consultation

During the first visit, a multidisciplinary consultation is held. It is considered preferable to treat patients at an early age for the following reasons: (1) the total surface area to be treated is less because the birthmark is smaller; (2) the lesion undergoes expansion and hypertrophy as the child becomes older, making it much more difficult to treat; and

(3) most importantly, the child is spared the psychological trauma and complications of growing up with a birthmark. At this time, the patient and family are informed of the following: (1) laser treatment may consist of multiple treatments given over many months; (2) there is transient edema and discomfort immediately following treatment; (3) a blue-gray discoloration of the treatment area will appear immediately following the treatment and will last for 10-14 days; (4) gradual lightening of the lesion will occur over two to three months following treatment; and (5) the possible risk of adverse reactions (scarring, infection, and transient hyperpigmentation). This discussion gives the patient and family the opportunity to raise any outstanding questions before written, informed consent is obtained (Figure 1a).

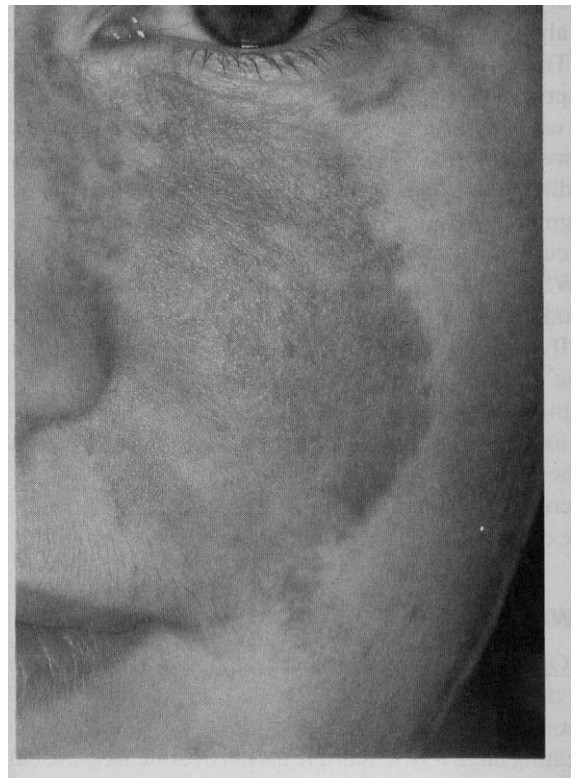


FIG. 1a. Twelve year old female child with extensive left facial port-wine stain prior to treatment.

### Test Areas

Following consultation, test areas are performed. Optimum therapeutic energy density is dependent upon patient skin type and individual variations occur from patient to patient. The physician makes several test areas at sequential energy densities beginning at an energy density of  $4.5 \text{ J/cm}^2$  on inconspicuous sectors of the lesion to be or

treated (high on the hairline, behind the ear) that are representative of the entire PWS. The energy density for each succeeding test area is increased by 0.25 J/cm<sup>2</sup> (4.75, 5.0, 5.25, 5.50 J/cm<sup>2</sup>, etc) to a maximum of 6.5 J/cm<sup>2</sup>. At each chosen energy density the PWS is irradiated with four to five laser pulses overlapped by 25-33% of the beam diameter. The degree of overlap of laser pulses appear to be a matter of personal preference, without any data to support one approach over another. By treating test areas with several energy densities, the density that will produce the best therapeutic response (blanching) can be determined.

A diagram of the patient's lesion showing the location of the test sites and energy densities is kept on file. All test sites are photographed pre-and postoperatively noting the energy densities used at each to enable better follow-up evaluation. No care is required of the threshold test sites.

Test areas are evaluated at 8-12 weeks at which time the appropriate energy density for treatment of the lesion can be established. The goal of test dosing is to determine the lowest energy density that results in significant-complete fading of the PWS without causing textural or permanent pigmentary changes in the skin. If significant lightening occurs with no unwanted effects, the remainder of the PWS can be treated safely using the energy density that produced the best test area results.

If none of the test sites shows lightening, this implies that the PWS may require higher energy densities for significant fading to occur. The energy density is increased in increments of 0.25 J/cm<sup>2</sup> up to a maximum of 7.5 J/cm<sup>2</sup>, where the potential for adverse effects is more likely to increase. Only rarely, with hypertrophic PWS in children, are energy densities of 7.5 J/cm<sup>2</sup> and higher required.

## PWS Treatment

Once the optimal light has been determined, treatment of the entire PWS may be started. For small PWS, the entire lesion may be treated in a single session. When treating large PWS, multiple partial treatments are usually required. Areas on face, trunk and extremity lesions are overlapped by 25-33% of the beam diameter. This is best done by moving the laser handpiece in a methodical fashion across the PWS such that adjacent areas are treated in order. Overlapping seems to result in a more even fading of the PWS and does not leave the checkerboard or lattice-like pattern seen when spaces are left between areas. On the neck and "V" of the upper anterior chest, however, areas are overlapped minimally or not at all in an effort to avoid blistering. On these sites, areas of 4-5 mm

between each pulse are "skipped" initially. Later in the same treatment session, these areas are filled in to achieve a uniform purpuric discoloration.

Although controversial, the author's believe there are definite psychosocial and clinical advantages to treating infants and young children by using general anesthesia including: (1) the experience is less emotional to the child, parents and physician; (2) larger areas can be treated more comfortably; and (3) a decrease in peripheral vascular resistance and vasodilatation permits a higher concentration of the targeted HbO<sub>2</sub> in the ectatic vessels.<sup>14</sup> However, general anesthesia brings an element of risk to a procedure that is otherwise essentially without risk to the general health of the infant and increases the cost of the procedure considerably. The option of restraint of the infant, possibly with sedation in addition, should be considered.

Older children, adolescents and adults are treated similarly with the exception that little or no anesthesia is usually required. Each pulse of the laser is generally described as feeling like a "rubberband being snapped against the skin" or a tolerable mild-moderate "pin prick sensation." If patients complain of pain, a local or regional block can be performed with lidocaine. Buffering of the lidocaine with sodium bicarbonate just prior to injection can reduce the discomfort of local anesthesia.<sup>15</sup>

EMLA<sup>(R)</sup> (Eutectic Mixture of Local Anesthetics) 5% cream (Astra Pharmaceuticals Ltd., N. Hyde, Australia), a mixture of lidocaine and prilocaine in an oil-in-water emulsion, under occlusion for 60-120 minutes has been helpful in some individuals. EMLA has been used extensively in Europe and found to eliminate the need for local anesthesia in cutaneous laser surgical procedures.<sup>16</sup> This new analgesic should be available soon for topical use in the United States, pending FDA approval.

## Posttreatment Skin Changes and Care

Immediately after treatment, a blue-gray ashen discoloration is seen. The ensuing color deepens, becoming blue-black in the first few hours after therapy (Figure 1b). This discoloration will usually last 7-14 days at which time the normal-slightly faded preoperative skin color will return. Additional fading of the PWS will be noted over the next several months.

Other changes noted in the immediate postoperative period include: swelling, hyperemia of the surrounding normal skin and mild postoperative pain that is often described as a "skin tightening" or feeling like sunburn. Appropriate relief is usually achieved with ice packs, cooling soaks, mild analgesics (acetaminophen, ibuprofen)

the application of emollients such as aloe vera gel, which seems to be preferred because of its immediate cooling sensation. Both the swelling and hyperemia are transient, usually resolving spontaneously in 24-72 hours. No wound dressings are required. Patients are instructed

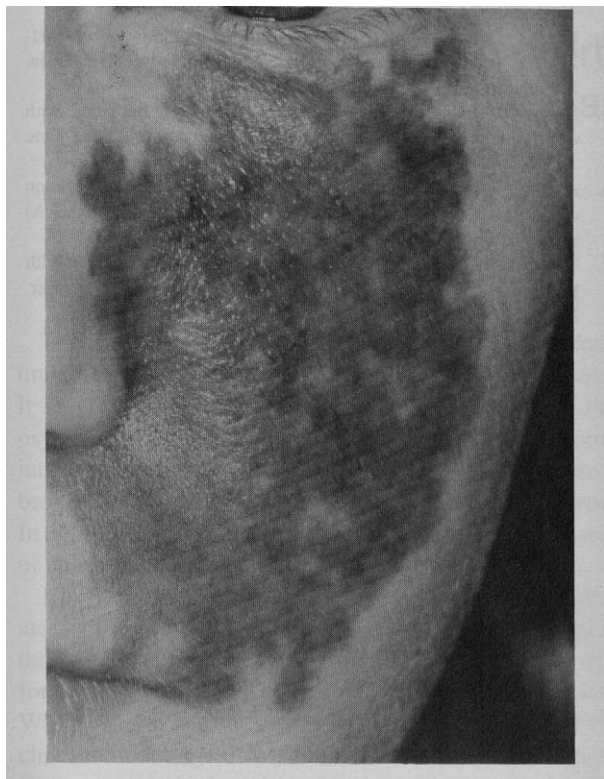


FIG. 1b. Twelve year old female child with extensive left facial port-wine stain immediately after laser irradiation of entire lesion.

to keep the area trauma free, and to apply a topical antibiotic ointment should any scaling or crusted areas develop. There are no activity limitations or restrictions. Patients are cautioned to avoid excessive sun exposure and advised to use adequate sun protection with clothing, hats and the daily application of sunscreen with an SPF (sun protection factor) of 15 or more, for at least three to six months after treatment, to prevent hyperpigmentation.

### Additional Treatment and Retreatment

Complete lightening of PWS after one treatment is considered rare. The great majority of patients require multiple treatments to the same area to obtain optimal fading. The number of treatments per lesion varies depending on the anatomical location. Lesions overlying bony prominences, such as the forehead, temple, and nose

generally require fewer treatments as compared with those on the cheek and lips. PWS on the trunk and extremities require more treatments but do respond. Children less than 7 years of age generally require fewer treatments for optimal response than do older children. Flat, immature PWS respond best. Mildly hypertrophic PWS flatten and lighten substantially. Nodular hypertrophic PWS respond least. Retreatments are usually performed at 8-12 week intervals. Retreatment energy densities can be held constant, increased or decreased by 0.25-0.50 J/cm<sup>2</sup> depending on clinical results. Pre- and posttreatment photographs provide documented evidence on the progress course of therapy which many patients and their families are unable to assess objectively (Figure 1c).

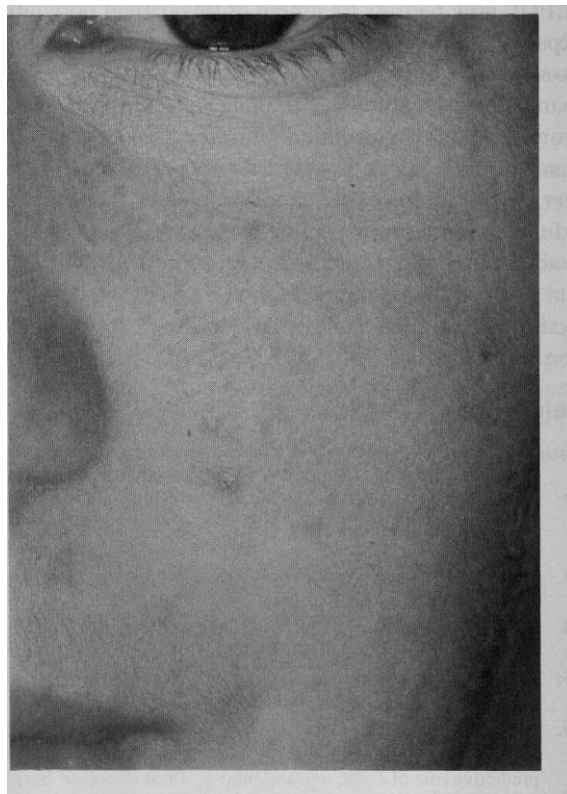


FIG. 1c. Twelve year old female child with extensive left facial port-wine stain six months after fourth laser treatment.

### Adverse Effects

The safety of this form of therapy has been demonstrated by the successful management of many infants and young children with PWS.<sup>17</sup> The immediate posttreatment purpura, edema, and erythematous flare within 24 hours to several days. The scaling and/or crusting that occurs

occasionally is also transient and resolves without any significant sequelae.

In contrast to other laser systems, minimal (less than 2%) or no scar formation occurs following the use of FLPDL. The majority of scars have occurred in areas accidentally traumatized soon after laser therapy. Hyperpigmentation, which has been reported in up to 57% of patients,<sup>17</sup> is usually temporary and will resolve spontaneously over 6-12 months or with the subsequent use of a hydroquinone bleaching preparation.

## Conclusion

While other laser modalities have incurred a high incidence of complications in infants and young children, the FLPDL now permits treatment of this patient population expected to gain the most benefit from early laser therapy, in a much safer manner. Most importantly, the child is spared the psychological trauma and complications of growing up with a birthmark. For this reason, the physician and biomedical support team have performed a real service to both the patient and the family.

Information for prospective patients and local referrals to academic regional medical centers in the United States that currently have the FLPDL can be obtained by contacting the National Congenital Port-Wine Stain Foundation (212) 755-3820 or (516) 775-3246).

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