STUDY

Treatment of Port-wine Stains With a Noncoherent Pulsed Light Source

A Retrospective Study

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Objective: We investigated whether a noncoherent intense pulsed light source (IPLS) would be effective in therapy of port-wine stains (PWSs).

Design: To evaluate the efficacy in treatment of PWSs with IPLS, a retrospective study was initiated.

Setting: The data were collected by physicians working in private practices and departments of university hospitals and medical centers, respectively.

Patients: A total of 37 randomly selected patients with a total of 40 PWSs were included in the study. Clinical PWS characteristics recorded were color and location of the PWS.

Interventions: All patients were treated with IPLS.

Main Outcome Measures: Data collected included treatment parameter (filters, pulse duration, fluence, and pulse sequencing), percentage of clearance, and side effects (purpura, blisters, crusting, altered pigmentation, and scarring).

Results: Good and complete (70%-100%) clearance was achieved in 28 of 40 PWSs treated with IPLS. The average number of treatment sessions in PWSs reaching 100% clearance included 4.0 for pink PWSs and 1.5 for red PWSs. The average number of sessions for purple PWSs reaching good clearance (70%-99%) was 4.2 sessions. Parameters used most frequently were 515- and 550-nm cutoff filters, pulse duration of 2.5 to 5.0 milliseconds, and fluences of 24 to 60 J/cm^2. Side effects included purpura in 133 (76%), superficial blisters in 14 (8%), and crusting in 35 (20%). Transient pigmentation changes were seen in 10.8% of patients (hypopigmentation in 3 [8.1%], hyperpigmentation in 1 [2.7%]). No scarring was observed.

Conclusion: Intense pulsed light source presents an effective and safe method for treating PWSs, especially purple PWSs.

Arch Dermatol. 1999;135:679-683

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PORT-WINE STAINS (PWSs)—a congenital, progressive ectasia of the superficial cutaneous vascular plexus—appear in 0.3% to 0.5% of newborns. At birth, PWSs are typically flat, sharply delineated, light-red lesions, often occupying large surface areas. Facial PWSs often occur in the region of the first and second trigeminal nerves. With time, these superficial vessels become more and more ectatic resulting in a darkening and thickening of the PWS, occasionally progressing to the nodular type with increasing age.[1-5]

Previous methods of treating mature PWSs included surgical solutions such as excision and dermabrasion, carbon dioxide cryotherapy, sclerotherapy, irradiation, and radioactive implants.[2,6] These treatments frequently result in associated complications, such as scars or pain. Irradiation-induced tumors as rare complications are known.

A variety of laser systems have been used, such as the argon, potassium-titanyl-phosphate, krypton, and copper vapor lasers and most recently, the flashlamp pulsed dye laser (FLPDL).[6-10] On theoretical grounds alone, the wavelengths that would best match oxyhemoglobin's absorption peaks are 418, 542, and 577 nm.[11] The FLPDL at 577 nm and later modified to 585 nm (allowing a greater depth of penetration while maintaining vascular selectivity) has proven to be the therapy of choice because of high efficacy and low incidence of side effects such as scarring.[5,12-15] However, efficacy for dark and particular nodular PWSs in adults is low most likely due to its relatively short-pulse duration (450 microseconds) and limited depth of penetration (maximum depth, 1.5 mm).[6,16] New laser systems like the flashlamp–pumped pulsed tunable dye laser (ScleroPlus Laser; Candela Corporation, Wayland, Mass; Millenium; Cynosure, Bedford, Mass) that permit the choice of longer wavelengths (585-600 nm) and longer pulse widths (1.5 milliseconds) have become available for the treatment of vascular lesions such as leg telangiectasia.[14,17-19] A long-pulsed potassium-titanyl-phosphate laser at 532 nm al-

PATIENTS AND METHODS

From October 1994 to January 1997, 37 patients (25 females, 12 males), with 40 PWSs were treated using IPLS (Photoderm VL; Shasplan-ESC Medical System Ltd, Yokneam, Israel) emitting noncoherent light with a continuous wavelength ranging from 500 to 1000 nm (spectral output of the optical treatment head [see **Figure 1**]). By using cutoff filters (515, 550, 570, 590 nm), shorter wavelengths are filtered out. A single-, double-, or triple-pulse sequence can be administered. Pulse duration ranges from 0.5 to 25 milliseconds in the short-pulse mode and up to 30 milliseconds in the long-pulse mode. Delay between pulses can be adjusted between 10 and 500 milliseconds; fluences from 3 to 90 J/cm^2 are attainable, and the surface area is large: 2.8 cm^2 (8 × 35 mm).

The patients were randomly selected from our own treated populations. Patient demographics were as follows:

Characteristics	No. of Patients or PWSs
Males	12
Females	25
Age range, y	
1-68	37*
Fitzpatrick skin type	
I	3
II	22
III	12
IV-VI	No data
PWSs (n = 40)	
Pink	14
Red	15
Purple	11
Localization of PWSs	
Face	20 (no periorbital)
Neck	6
Trunk	6
Extremities	8
Previously treated PWSs	12 (5 red; 7 purple)
Argon and/or dye laser	11
Cryotherapy	1
Localization of treatment	
Face	6
Neck	1
Trunk	2
Extremities	3
Local anesthesia with Emla cream (combination drug: 2.5% lidocaine hydrochloride and 2.5% prilocaine cream)	6 (among 2 children)

**Among the 37 patients 1 was 1 year old; 2, 4 years old.*

All treatments were performed using a clear, cooled, proprietary water-based gel (Coupling Gel; ESC Medical System Ltd) placed between the emitting crystal and the skin to decrease the heating of the epidermis. Following treatment, a cool compress was placed on the area for 20 to 30 minutes. Therapy with topical antibiotics or steroids was not required posttreatment. Patients were treated with IPLS intervals of 4 weeks and longer.

Due to the retrospective character of our study and different investigators, no uniform treatment parameters were used. The filters used were 515, 550, and 570 nm; total fluence ranged from 24 to 60 J/cm^2, and energy was applied in single-, double-, and triple-pulse sequences. First the PWSs were treated in the single-pulse mode. In case of nonresponse, total fluence delivered was increased by using double and triple pulses, until an immediate response of erythema or purpura was seen. Intense pulsed light source was used in only 1 case (purple PWS) in the long-pulse mode (590 nm, triple pulse) with a high fluence of 70 J/cm^2.

Photographs of all sites were taken under identical conditions. Identical cameras (Cannon EOS 100) with Agfa CTX 100 film were consistently used (except for Nikon N90 with Canfield flash system and Ektachrome 100 film at one site). Pretreatment and posttreatment photographs were reviewed by 3 nonparticipating physicians to evaluate lightening of the lesions independently. Using special colorboards the degree of clearance was determined as a percentage of reduction in color relative to normal skin. Results were ranked into 1 of 4 categories: complete, 100% clearance; good, 70% to 99% clearance; fair, 40% to 69% clearance; and poor, less than 40% clearance. Presence or absence of posttreatment blisters, purpura, crusting, hypopigmentation or hyperpigmentation, or scarring was recorded corresponding to data in patients' documents. For statistical analysis the average parameters and SD were determined.

lows for the use of variable pulse widths in the 1- to 50-millisecond range (Aura; Laserscope, San Jose, Calif; Versapulse; Coherent, Palo Alto, Calif).[10,20-22] Deeper penetration can be reached and with longer-pulse durations, which lie closer to the thermal relaxation times of larger vessels,[23] more effective thermal coagulation can be achieved.

Intense pulsed light source has been thought to present another alternative for vascular lesions composed of larger vessels. This high-energy flashlamp emitting noncoherent light and providing a wide range of various treatment parameters (wavelength, pulse duration, pulse sequences) has been used effectively in the treatment of cavernous hemangiomas, venous malformations, facial and leg telangiectasias, spider nevi, poikiloderma of Civatte, and hypertrichosis.[24-30]

The IPLS functions are also based on the principle of selective photothermolysis.[11] By using the appropriate wavelength and delivering sufficient energy within the thermal relaxation (cooling) time of the target chromophore (oxyhemoglobin in vessels in PWSs), it is possible to specifically damage selected targets within the tissue. By applying long pulses and multiple-pulse sequences, and by splitting up higher-energy densities, IPLS allows the treatment of larger blood vessels and cavernous vascular lesions. Longer wavelengths allow for the heating of deep-lying vascular structures.

Treatment of PWSs was performed using these principles during the multicenter clinical study of IPLS.

RESULTS

The mean (± SD) number of sessions was 2.9 ± 2.87 for pink PWSs, 2.0 ± 1.56 for red PWSs (SD), and 4.0 ± 1.87 for purple PWSs. It is noteworthy that the 70% to 99% clearance of pink PWSs occurred with an average

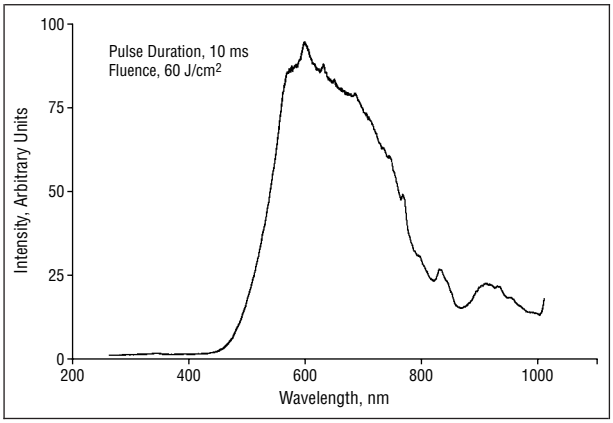

Figure 1. *Emission spectrum at the optical treatment head without cutoff filter only including a fixed mandatory blocking filter (pulse duration, 10 milliseconds; fluence, 60 J/cm²). (Figure the courtesy of Holger Lubatschowski, PhD, Laser Zentrum, Hannover, Germany.)*

Table 1. Degree of Clearance in Previously Untreated Port-wine Stains* in Relation to Their Color

Clearance, %	Port-wine Stain			Total, No. (%)
	Pink	Red	Purple	
100: Complete	5	2	0	**7** (25.0)
70-99: Good	6	6	2	**14** (50.0)
40-69: Fair	3	1	2	**6** (21.4)
<40: Poor	0	1	0	**1** (3.6)
Total	**14**	**10**	**4**	**28 (100.0)**

**n = 28 (number of positive stains).*

Table 2. Degree of Clearance in Previously Treated Port-wine Stains* in Relation to Their Color

Clearance, %	Port-wine Stain			Total, No. (%)
	Pink	Red	Purple	
100: Complete	0	1	0	1 (8.3)
70-99: Good	0	2	4	6 (50.0)
40-69: Fair	0	1	3	4 (33.4)
<40: Poor	0	1	0	1 (8.3)
Total	**0**	**5**	**7**	**12 (100.0)**

**n=12 (number of positive stains).*

Table 3. Frequency of Side Effects Following Noncoherent Pulsed Light Source Treatment*

	Port-wine Stain			No. of Side Effects	% of Total No. of Treatments (n = 175)
	Pink	Red	Purple		
Purpura	38	38	57	133	76
Long-term swelling	0	2	0	2	1
Blisters	2	5	7	14	8
Crusting	4	8	23	35	20
Hypopigmentation, No. of patients	1	2	. . .	3	8.1†
Hyperpigmentation, No. of patients	. . .	1	. . .	1	2.7†

**Ellipses indicate that there is no hypopigmentation in patients with purple port-wine stains and no hyperpigmentation in those with pink or purple port-wine stains.*

†Indicates percentage of patients.

(± SD) of 2.8 ± 2.13 sessions; red, with 1.4 ± 0.53 sessions; and purple, with 4.2 ± 2.59 sessions. In 5 of 14 pink PWSs, 100% clearance was observed after 4.0 ± 4.69 sessions. Two of 15 red PWSs showed an complete clearance after 1.5 ± 0.70 sessions (mean ± SD). There was no 100% clearance in purple PWSs.

Most of the pink and red PWSs (48% and 53%, respectively) were treated mostly with the 550-nm filter, while dark PWS (46%) required the 515-nm filter. The latter was very often used by 2 of us. In 136 (77.7%) of the total sessions a single pulse was applied. For single pulses, the 515-nm filter with a 2.5-millisecond–pulse duration was most frequent (66 [48.5%]). The 550-nm filter with a 5-millisecond duration was required in 53 (38.9%). Double pulses and triple pulses were used but less frequently (25 [14.3%] and 26 [14.8%], respectively). Energy density ranged from 24 to 60 J/cm². The mainly used fluence in the single-pulse mode was 28 to 30 J/cm².

Treatment results for previously untreated PWSs (n = 28) included 7 completely cleared (5 pink and 2 red); 14, good clearance (6 pink, 6 red, and 2 purple); and 6, fair clearance (3 pink, 1 red, and 2 purple). One case of a previously untreated red PWS demonstrated poor results (**Table 1**).

Previously treated PWSs (n = 12) showed 100% clearance in 1 case of red PWS. Good clearance was recorded in 6 cases (2 red and 4 purple), while 4 PWSs (1 red and 3 purple) demonstrated fair results. One red PWS showed poor clearance (**Table 2**).

In summary, complete and good clearances (70%-100%) were recorded in 21 (75%) of the previously untreated PWSs in contrast to 7 (58.3%) of the previously treated PWS.

Side effects included immediate erythema in all sessions and immediate purpura in 76% of the sessions, persisting for a maximum of 7 days, typically 24 to 72 hours. Immediately after treatment, swelling lasting only several hours was common. Swelling persisting longer than 24 hours and blisters were rarely observed following treatment with higher fluences (2 [1.1%] and 14 [8%], respectively). In 35 (20%) of the sessions, crusting was noted that resolved within 1 to 2 weeks (**Table 3**). Hypopigmentation was seen in 3 (8.1%) of the patients, and hyperpigmentation in 1 (2.7%) of the patients. These resolved within 2 to 4 months. No scarring or textural change resulted. An illustrative case is shown in **Figure 2.**

COMMENT

The application of light in blue-green to yellow wavelengths results in selective damage of cutaneous vascular structures secondary to heating of hemoglobin as illustrated by most successful uses of FLPDL (at 577 or 585 nm; pulse duration, 0.45 milliseconds) for elimination of PWSs.[3,4,31-33]

The primary limiting factor of FLPDL is the small depth of penetration. Findings from histological studies demonstrated insufficient coagulation of dermal vessels

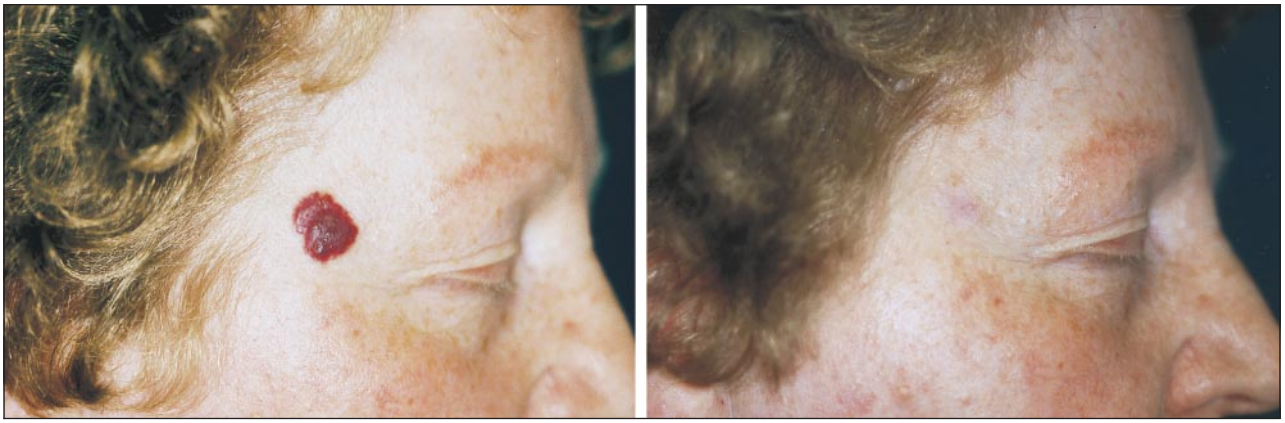

Figure 2. *Left, A 56-year-old woman with a slightly raised purple port-wine stain on the right temple. Right, Ninety-nine percent clearance following 6-time therapy with the intense pulsed light source laser (1 treatment with 515-nm; 2, 550-nm; 2, 570-nm; and 1, 590-nm filters; pulse duration, 2.5-8.5 milliseconds; 28-70 J/cm^2).*

below 1.16 mm in human skin.[34-36] Vessels lying beyond the limited penetration depth may persist and determine the clinical response. In a PWS 577- or 585-nm laser treatment model, it has been shown that most energy is deposited in the superficial vessels. Multiple vessels mutually influence one another: the presence of overlying vessels decreases the amount of light available to be deposited in deeper vessels (shadowing effects). By this modeling the smaller effective depth at which vessel destruction occurs (maximum depth, 0.65 mm) by FLPDL may be explained.[37] Our study corroborated this: 7 of 11 purple PWSs had been previously treated unsuccessfully with argon and/or FLPDL. The strong absorption of the 488- or /514-nm and the 577- or 585-nm wavelengths in blood prevents heating of the full wall diameter of large vessels and, therefore, only the top of the vessel is heated. Longer wavelengths penetrate deeper. However, the absorption of laser energy in blood vessels decreases dramatically.[18,36,38] Concomitant increases in fluence are required to compensate for the decreased absorption.[18] It has been shown that the use of 600-nm FLPDL with greater fluences (9.9 and 13.2 J/cm^2) provides a higher degree of clearance compared with 585-nm FLPDL at 6.6 J/cm^2.[39] The IPLS uses a broad spectrum of long wavelengths (515-1000 nm) and the necessary high fluences (up to 90 J/cm^2). Thus, effectively heating the upper as well as the deeper vessels of PWSs could be obtained. Our data show that 6 of 11 purple PWSs achieved a good clearance (70%-99 %) within an average of 4.0 and 4.2 sessions when using IPLS.

It has been shown that the clinical response of lightening in PWSs following FLPDL (at 585 nm; 0.45-millisecond pulse length; fluence of 6.5 J/cm^2) is dependent on vessel depth, diameter, and wall thickness. Port-wine stains with good responses were more superficially located (above 300 µm from the dermoepidermal junction) than those with moderate and poor responses. The moderate and good responding lesions consisted of moderate-sized vessels with diameters of 38 µm. The lesions showing poor blanching had smaller vessels (diameter, 19 µm). According to findings on histological examinations, there was also a tendency toward thicker vessel walls with increasing depth in the dermis.[34,40] Analytic modeling of the influence of wavelength on PWSs with different dermal blood content confirms that 577 nm is the optimal wavelength for treatment of pink PWSs (small vessels, < 14 µm).[38] This fact concurs with the studies of Tan et al,[5] that showed excellent results on pale pink lesions.

Ideally, the pulse duration should be compatible with the vessel diameter and be about equal to the thermal relaxation time for that dimension.[23,24,41] Dierickx et al[23] discussed the benefits of longer-pulse duration and concluded that pulse durations of 1 to 10 milliseconds allow destruction of 30- to 150-µm vessels while sparing the capillaries. Using tunable FLPDL (585-600 nm; 1.5 milliseconds) (ScleroPlus Laser; Candela Corporation; Millenium; Cynosure) and long-pulse frequency-doubled Nd:YAG laser (532 nm) (VersaPulse; Coherent; Aura; Laserscope), good results could be achieved in the treatment of ectatic blood vessels encountered in PWSs, telangiectases,[10,19-22] and leg veins smaller than 1 mm in diameter.[17,18] The IPLS providing pulse durations up to 50 milliseconds enables delivery of laser energy to vessels over longer periods of time, resulting in either gentle, uniform heating or even coagulation across the entire vessel, while reducing vessel rupture and its associated purpura and hyperpigmentation.[24,27,37,42,43] Therefore, IPLS can be seen as an additional mode of PWS therapy, particularly for dark and hypertrophic lesions.[26] It has been shown in a case report that FLPDL-resistant PWSs showed notable improvement following a single IPLS treatment.[42]

Using IPLS, splitting light into double and triple pulses is possible. Thus, larger and deeper vessels, such as in hypertrophic PWSs or venous malformations, which require higher fluences to reach sufficient coagulation, can be treated effectively by additive heating.[27,44] The epidermis and smaller vessels cool down during the long delay between pulses (10-500 milliseconds) without reaching coagulation temperatures or causing necrosis.[24] The ability to deliver multiple pulses to treat vascular lesions may have theoretical support since Dierickx et al[23] were able to achieve multiple-pulse photocoagulation of blood vessels using lower fluences.

In the current study, adverse reactions included superficial blisters in 8% and transient crusting in 20%, especially in purple PWSs. The use of higher fluences seems to cause epidermal damage owing to absorption and back scattering of light from especially large vessels to the sur-

rounding tissue. Hypopigmentation (8.1%) and hyperpigmentation (2.7 %) were relatively infrequent. Finally, scar formation was not seen in our patients. This approximately corresponds to the references with regard to the application of IPLS for leg telangiectases (blisters, 2%-42%; hypopigmentation, 3%-20%; hyperpigmentation, 4%-50%; scarring, 0.5%-21%).[24,25] In the treatment of PWSs, FLPDL caused comparatively frequent postinflammatory hyperpigmentation reported at a frequency of 9% to 57 %[5,6,32,35,46-48] and postinflammatory hypopigmentation in 2% to 10 %.[3,4,6,16,46] Hyperpigmentation and hypopigmentation were also the most common transient side effects of the long-pulsed FLPDL treatment of leg veins.[17,18]

The success rate with PWSs, particularly with FLPDL-resistant dark types, combined with a relatively low incidence of side effects, makes IPLS a useful alternative for adjunctive or primary treatment of PWSs. Whether IPLS will find a firm place in the therapy of vascular lesions, especially of PWSs, still awaits large, critical, and especially prospective clinical studies, and better refined IPLS treatment parameters.

Accepted for publication March 11, 1999.

We are grateful to Thorsten Reinke, MS, Math, and his team for the statistical analysis of our data.

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