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# Use of Flashlamp-Pumped Pulsed Dye Laser in the Treatment of Superficial Vascular Malformations and Ulcerated Hemangiomas

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**Abstract.** *A retrospective study of 502 patients treated with tunable flashlamp pulsed dye laser for superficial vascular malformations (433), ulcerated hemangiomas (65) and postinvolutional redness (4) is presented. Patients were treated in the period from June 1997 to March 2006, with follow-up ranging from six months to four years. The age of the patients ranged from three months to 80 years. Correlation between clinical response and patients' age, location of lesion and number of treatments were evaluated in groups of superficial vascular malformations, whereas healing rates of the ulceration were assessed in a series of hemangiomas. The result were judged to be excellent in 51%, good in 39%, fair in 7% and poor in 3% of patients with vascular malformations. Excellent ultimate outcome confirmed the clinical efficacy of the use of the pulsed dye laser in the treatment of dermal vascular malformations, which also appears to have good prospects in the management of hemangioma complication.*

Superficial vascular malformations (SVMs) are defined as congenital vascular malformations of the superficial dermal vessels, characterized by their abnormal dilatation, which become progressively ectatic over time, resulting in noticeable aesthetic deformity (1). SVMs affect 0.3-0.5% of newborns and never spontaneously involute, whereas two thirds of patients develop hypertrophy and nodularity by the age of 46 years (2-3).

SVMs may be associated with underlying venous, arterial or arterio-venous malformation, as well as with neurological disorders within Sturge-Weber, Kllipel-Trenaunay, Kllipel-Trenaunay-Weber and Cobb syndromes (1). However, the most common associated disease is glaucoma, which occurs in 45% of patients with an SVM involving the first two branches of the trigeminal nerve (3). Glaucoma is found in around 10% of patients with facial SVM, whereas approximately 3-6% of patients with leptomeningeal involvement have this complication (4).

Hemangiomas are benign vascular tumors composed of proliferative endothelial cells and are the most common tumors of infancy with a female/male ratio of 3:1 (3, 5). Hemangiomas can occur in skin, where they present themselves as superficial, deep cutaneous and subcutaneous proliferation, as well as in mucous membranes and other soft tissues (6). The majority, from 70% to 90%, appear during the first month of life, and by the age of one year the incidence is 10-12% (2-3). Unlike SVMs, hemangiomas undergo spontaneous regression in up to 85% of patients by the age of seven years (7). Mulliken *et al*. underlined that virtually 100% of angiomas undergo spontaneous regression, which is complete or almost complete in about 95% of patients (1). However, up to 15% of lesions do not completely involute, and yet, residual redness or telangiectasias are relatively common findings. Ulcerations occur in 5-11% of patients, particularly at sites exposed to trauma and friction such as the anogenital region, ears, nose and lips (3).

Through the years, many laser systems with their own specific properties have been judged favorable for treatment of the ectatic blood vessels in SVM. Recent publications have confirmed the sovereignty of pulsed dye laser in this field (8-17). Intolerable scarring, permanent hyper- or hypo-pigmentation and epidermal atrophy have been surpassed thanks to the remarkable selectivity of dye laser, which eliminates the abnormal vessels without impairment of adjacent structures. The concept of selective photothermolysis,

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Table I. *Characteristics of the lesions and of the treatments applied.*

| Lesion | Lesion size ($cm^2$) | Site distribution ($J/cm^2$) | Energy density | Treatments | Pulses | Interval between sessions (days) |
|---|---|---|---|---|---|---|
| SVMs | 3-900 | 227 Head and neck (66.3%)<br>58 Chest (10.6%)<br>54 Arm (9.2%)<br>46 Abdomen (6.6%)<br>48 Leg (7.3%) | 5.50-7.25 | 2-10 | 10-1500 | 40 |
| Hemangiomas | | 19 Genital<br>14 Perianal<br>9 Scalp<br>7 Lower lip<br>5 Upper lip<br>4 Abdomen<br>3 Forearm<br>3 Tip of nose<br>1 E7ar | 5.75-6.75 | 1-3 | 80-100 | 14-42 |

a fundamental laser principle applied to SVM therapy, is based on the absorption spectral peak of oxyhemoglobin at 577 nm. This pigment is presented in elevated concentration in the areas of abnormal vascular proliferations and it selectively absorbs the 577 nm light which determines the ablation of the altered vessels. It has been demonstrated that at this wavelength the laser does not alter integrity of epidermal cells, while in the dermis, damage is confined to SVM vessels and surrounding collagen, preserving the adjacent viable structures (18). Considering the wavelength as the most important parameter for achieving vascular-specific injury, Tan *et al*. increased the average dermal depth of vascular lesion from 0.72 to 1.2 mm by the application of a wavelength of 585 nm instead of 577 nm (11). Recently, van Gemert *et al*. explained through analytical modeling why 585 nm is a good compromise for treatment of SVMs that vary in number of dermal vessels (19). Onizuka *et al*. indicated the mean depth of vessels as the main prognostic factor in the treatment of vascular malformations and estimated a 95% confidence interval for the critical value from 830-1030 nm (17). Current pulsed dye lasers mainly operate in wavelength range from 575 to 585 nm, showing remarkable results.

Considering the pathogenesis and biological characteristics of hemangiomas, the most adequate therapeutic approach is to induce their involution and to prevent proliferation. This is partially realized through the use of systemic steroids and interferon 2 alpha, but it is beyond the scope of this paper (3-20). The role of the pulsed dye laser in the management of hemangiomas is reserved for the treatment of post-involutional redness and telangiectasias as well as for ulcerating lesions, where alleviation through to complete clearing and resurfacing with stable epithelium are achieved (21). However, recent investigations showed that even deep component of hemangiomas can be altered with a large beam diameter (22).

The purpose of this paper is to confirm the clinical efficacy of the flashlamp-pumped pulsed dye laser (FLPDL) in the treatment of SVMs and its indispensable role in the management of post-involutional lesions and complications of hemangiomas.

## Materials and Methods

A FLPDL (SPTL-1b, Candela Laser Corporation, Wayland, MA, USA) with an emission wavelength of 585 nm, pulse duration of 300-500 ms, energy density adjustable from 3.0 to 10 $J/cm^2$ and 7 mm beam diameter was utilized in this study.

*Patients*. The studied subjects comprised two groups: 433 patients (228 male and 205 female) treated for SVMs and 69 patients treated for ulcerated hemangiomas and post-involutional redness. The latter group comprised 65 subjects (18 male and 47 female) with ulcerations and four female subjects with residual redness. The ages of patients ranged from one month to 80 years (average 14 years) in the group with SVMs, and from three to fifteen months (average eleven months) and ten to twelve years in the groups with ulcerated hemangiomas and post-involutional lesions, respectively.

*Treatment protocol*

*SVMs*. The SVM series was subdivided into the following groups: 0-2 years, 2-12 years, 12-18 years and more than 18 years of age. Initiation test treatment had been performed in 104 patients (24.1%) of this group, to allow the patient and their family to understand the procedure and to assess the best energy density for subsequent treatments. Tests were performed on a small skin area with 3-5

different energy fluencies in increments of 0.25-0.50 J/cm$^2$. Forty days following the test treatment, these skin areas were evaluated for lightening and eventual complications. In the absence of the latter, the lower effective pulse energy was used for further treatments. The pulse fluency in 329 patients was determined by the investigators experience, and a test probe was not performed for this group. All laser sessions were performed at 40-day intervals to allow for adequate clearing of malformations, and the degree of clinical improvement was a fundamental parameter for further therapy maneuver. Lesion size varied from 3 to 900 cm$^2$ (mean 234 cm$^2$) while site distributions included head and neck (227 patients, 66.3%), chest (58 patients, 10.6%), arm (54 patients, 9.2%), abdomen (46 patients, 6.6%) and leg (48 patients, 7.3%). The surface of an entire lesion was treated in each single session. Twenty-three patients (twelve male and nine female) had two different lesion sites and the clinical response was evaluated separately.

The patients were treated with overlapping pulse spots of up to 1/3 diameter to achieve more uniform results, as advised by many investigators (14, 23-24). The treatments were performed on an outpatient basis without anesthesia in adults. The children aged one month to twelve years underwent mild sedation or general anesthesia with inhalation agents (Diprivan: ICI-Pharma, ICI Italia S.p.A., Milan, Italy; Fluothane: Zeneca S.p.A., Milan, Italy). Each treatment was accomplished with application of Foil ointment (S.p.A Labatori Delalande Isnard, Gruppo Synthelabo, Imperia, Italy). Results were assessed in lightening percentage from 0-100% as excellent (75-100%), good (50-75%), fair (25-50%) and poor (0-25%). Reviewing and evaluations were performed after each session and at completion of treatment. Complications were defined as presence of persistent hypo-, hyper-pigmentation or epidermal texture changes. All patients were photographed before initiation of the treatment as well as before and after subsequent treatment sessions. Pre- and post-operative standardized photographs were projected simultaneously and the clinical responses of each patient were independently examined by five cooperating doctors.

*Hemangiomas*. Ulcerated lesions varied in appearance from flat red (16 patients), through slightly raised (26 patients) to raised with marked subcutaneous component (25 patients). Energy fluencies were determined upon individual characteristics of each lesion, taking care to deliver the lowest density which provoked coagulation. Topical antibiotics were applied after each session, and continued for several days until scar formation appeared. Progress of therapy was evidenced by routine photography before and after treatments. Moreover, the patients were examined between the sessions and the results were re-evaluated in the follow-up period. Treatments were conducted at 15 day intervals and were interrupted when the whole ulcerated area was resurfaced with stable epithelium.

Four subjects with post-involutional redness were treated according to the principles of laser therapy of vascular malformations. Table I summarizes all the data described.

## Results

*SVMs*. Characteristic purpura appeared after each treatment and faded within six to twelve days (average nine days). Residual erythemas were present in 21% of cases and this resolved in up to five days. The patients with frontal and palpebral involvement developed significant peri-orbital edema with maximum expansion in the first 24 hours and resolution within two to three days after a session.

Among the treated subjects, 51% had excellent results, 39% had good, 7% had fair, 3% had poor results. Treatment of one patient failed to show any significant clinical fading despite repeated exposures (ten) of the same area to different energy fluencies during 14 months. Since all the instrumental analyses (NMR, fluximetry, echo-colour Doppler, thermic flux, thermic echography) confirmed the diagnosis of vascular malformation, failure of therapy led the Authors to believe that it was a border line lesion.

In the category of excellent results, an average skin lightening effect of 60% was obtained after the first treatment, which increased to 75-100% after following treatments. In the good, fair and poor categories, the skin lightening effects after first session were 45%, 20% and 10%, increasing up to 50-75%, 25-50% and 15-25%, after successive sessions, respectively. Energy density varied between 5.50 and 7.25 J/cm$^2$ (average 6.34 J/cm$^2$), and the number of treatments varied from 2 to 10 (mean 4.2), while number of pulses administrated during one treatment session ranged from 10 to 1500 (mean 156). Overall, 91 patients had more than 80% skin lightening after an average of 3.4 treatments (range 2-6). An improvement of 68% was found in those lesions not clearing completely and classified in category good after a mean of 3.8 treatments (range 3-8). Lesions with poor and fair results had an average improvement of 34% after mean 5.3 treatments (range 3-11).

Favorable response was highest for head and neck malformations (93%), satisfactorily high for chest, abdomen and arm (90%, 54% and 41%, respectively) and the lowest for SVMs of the legs (39%). Lesions situated on the lower third of the leg were less responsive to treatment and had the highest proportion of poor results (60%).

Complications were minimal. Crust formation developed in 20 patients, mainly after use of higher energy densities, but with no skin sequelae in follow-up period. One subject developed hyperpigmentation, which did not fade during the following seven months and required additional $CO_2$ laser removal. No hypopigmentation, scarring or any clinically evident epidermal texture changes were noted.

*Hemangiomas*. A complete clearing (100%) was achieved in four patients with post-involutional lesions after 6 to 18 weeks following one to three treatment sessions (mean 2.1). The average energy fluency was 6.25 J/cm$^2$ (5.75-6.75 J/cm$^2$) and the number of pulses delivered in one treatment ranged from 80-100 (mean 93). All lesion sites were on the face and treatment did not cause any temporary or permanent epidermal changes. Response in the patient group with ulcerations was excellent, with no exceptions. Gradual resurfacing of all ulceration was achieved, no matter what the lesion characteristics were, requiring one to three sessions per patient


Figure 1. *A: A six-month-old child with SVM involving the left forehead, temple, eyelids, nose cheek, lip, ear and neck after the first FLPDL treatment session; B: The result following five FLPDL treatments.*


Figure 3. *A: Pre-treatment appearance of a SVM involving the right side of the face of a three-year-old child; B: The result following five FLPDL treatments.*

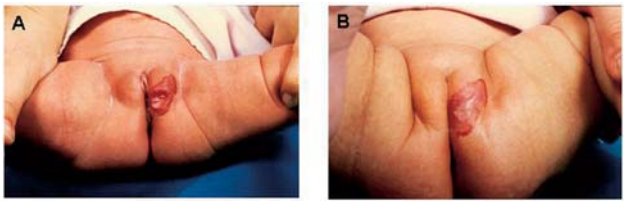


Figure 2. *A: Pre-treatment appearance of an ulcerated genital hemangioma in six month old girl; B: Final result 12 days after second FLPDL session.*


Figure 4. *A: Pre-treatment appearance of a SVM involving the left side of the face of a 25-year-old woman; B: The result following two FLPDL treatments.*

(mean 1.5). Energy density varied from 4.75 to 5.50 J/cm$^2$ (average 5.12 J/cm$^2$). Scar formation healed within 6-21 days following treatment, which allowed a subsequent treatment session if necessary. Complete re-epithelialization of the lesions occurred in two to six weeks from initiation of treatment. The distribution of lesion sites was: genital (19 patients), perianal (14 patients), scalp (9 patients), lower lip (7 patients), upper lip (5 patients), abdomen (4 patients), forearm (3 patients), tip of the nose (3 patients) and ear (1 patient). None of the possible complications associated with laser treatment were noted. However, some scarring was noticed but it did not differ from healed hemangiomas treated conservatively.

All treated subjects were followed-up in a period of 6-48 months and no sign of relapse was noted.

In Figures 1 to 4, four different cases are presented, showing the effects of FLDPL treatments on different lesions.

## Discussion

The introduction of the dye laser in clinical practice with its extraordinary low incidence of permanent sequelae has changed the number of patients with vascular malformations. The risk of scarring caused by less specific techniques, which once were valuable treatment modalities, is markedly reduced with this source of light.

The results in the treatment of SVMs in the current study are consistent with previous reports on the efficacy, specificity and advantages of FLPDL laser. Although some investigators have noted that dye laser has obtained particularly good results in the youngest patients (9-10, 25), the current findings support those articles where no correlation between age and efficacy was found (14, 17, 26). It should be noted, however, that the lowest number of treatments was required in the group of children aged three months to two years with light lesions (mean 2.7 sessions) and this is consistent with the results also reported by Tan *et al.* (27). This phenomenon can be attributed to the small size of lesions as well as to adequate inter-

treatment interval which did not permit a vascular re-growth. The results presently available are in accordance with these findings, though Alster and Wilson reported a significantly higher number of treatments in this age group (8). The most favorable response was obtained in subjects with face and neck malformations (Figures 1 and 2), while the less favorable responses were displayed in subjects with lesions in the lower extremities. These findings correspond with previous reports on the efficacy of FLPDL (9, 17, 23, 28-30). Patients with malformations in the distal third of legs showed the least skin lightening effect (average 12%) and exhibited poor results in nine out of eleven cases. The number of subjects is small, but the proportion is still indicative, confirming that anatomical location of SVMs influences the response to laser therapy. However, the factors that influence this relationship are still indistinctive as the skin thickness of the chest, upper and lower extremities, considered to affect the laser permeability, has been found to be the same (31). While some authors attribute this occurrence to microstructure of the skin (32), Onizuka *et al*., through histopathological analysis, concluded that the vessels in patients with favorable response tend to lie less deeply than in the group with unfavorable response, irrespective of the treated site (17).

The present study confirms the high specificity of this source of light. Absence of the epidermal changes or scarring at the laser exposed site, after multiple applications and with excellent lesions lightening are a convincing argument. Previous publications have described the ability of dye laser to re-treat an affected area with continued improvement and no increase of complications (13, 24, 33). In the present study, the crust formation was not considered as a complication, since it resolved with no scarring or change of skin texture.

One patient displayed permanent darkening of the treated site and this was addressed by use of excessive energy fluency (7.25 J/cm$^2$) and the leg involvement, as noted also by other authors (8, 24).

The number of treatments required to achieve the desired results are nearly identical to those reported in other studies and multiple sessions were found to be necessary in 83% of cases (14, 17, 24). Regarding the results, it must be underlined that the personal evaluation of patients or their parents was the principal parameter for the interruption of therapy. We agree with Reid *et al*. that the entire lesion should be treated in each session no matter how extensive it is, for at least two important reasons (14). Firstly, together with proper inter-treatment interval, it disables possible re-growth of the pathological blood vessels from adjacent untreated regions. Secondly, it significantly reduces the number of sessions and shortens the skin lightening period, *i.e*. the duration of treatment, which is particularly appreciated by patients and parents.

The current study suffers from the disadvantage of lacking in the correlation between response, vessels depth and structure of the skin, the factors considered to principally influence the effectiveness of dye laser (17, 29, 32). Unfortunately, there were great difficulties in obtaining the histological investigations which are essential for this kind of investigation. Considering the arguments that smaller spot size produces significantly more nonspecific tissue damage than a larger one (34), and that the latter theoretically allows deeper vascular injury (22), a beam diameter of 7 mm was chosen in all instances in this study. This might be the substantial factor that influenced the absence of complications in these patients.

Although the treatments generally did not require anesthesia of any type in adults, they were still a sufficiently painful and stressful procedure in children. Many authors recommend a deep sedation or general anesthesia in cases of non-cooperating patients (2, 35-37). The experience of these authors indicates that these two methods are necessary in children aged up to 12 years, but also in the patients older than 12 years with lesions covering large areas, or situated around the eyelids and mouth.

It should be noted that in two cases there were fire incidents during the administration of general anesthesia through a face mask, fortunately with no consequences to patients or team members. Most likely it was the result of oxygen leakage from the mask into the laser field, as reported by Epstein and Halmi, and the risk of fire during laser sessions under general anesthesia has to be taken seriously into consideration (38).

In spite of many attempts and with respect to the findings of some authors, the use of topical anesthesia did not yield encouraging results in our hands (8, 10, 40). An interesting new approach for overcoming the pain and discomfort during the FLPDL treatment using iontophoresis of lidocaine was reported by Kennard and Whitaker (37).

Several studies have been conducted to assess the possible role of FLPDL in treatment of hemangiomas which have been generally expectant in the absence of complications or cosmetic disfiguration (2, 10, 22, 40). The results of a publication by Scheepers and Quaba revealed several aspects of laser treatment of these lesions (21). Among others, they noted that the treatment speeded up the healing rate of the ulcerating lesion, leaving a stable epithelium on the affected area. With regard to the same problem, Geronemus noted that FLPDL is more efficacious in treatment of the ulcerated hemangiomas when they are in the involution phase rather then when the lesion is proliferating (10). The current study generated data demonstrating a remarkable ability of FLPDL in obtaining the steady cover in lesions with this complication, whether the ulceration resulted from natural evolution of hemangiomas or from abrasion when found in regions exposed to trauma. A lack of patients with lesions in involution made any conclusion related to treatment efficiency and involutional or proliferative phases of hemangiomas impracticable.

Of significance was the conservation of the same healing rate of lesions in the genital and perianal region, where permanent contamination and irritation is present (Figures 3

and 4). Furthermore, since all the subjects were treated on an outpatient basis, which is by itself an advantage of the dye laser therapy, the necessary cooperation of the parents was also provided through patients' pain relief. Namely, during the healing process, painful ulceration became painless fast enough to reassure the parents and to confirm the adequate indication for FLPDL application. It should be noted that Achauer and Vander Kam, as well as Apfelberg, obtained nearly identical results with argon and Nd: YAG laser with direct injections of steroids (41-42). The current study revealed FLPDL as a safe and effective treatment of this complication.

The patients with hemangiomas without complications were excluded from this study, although it has been shown that at least flat lesions can be successfully treated (21). Four patients with post-involutional redness were insufficient for any kind of analysis, but they are able to illustrate the key role of FLPDL in treatment of these residues, already reported in the literature (21).

In conclusion, superiority of FLPDL over other treatment modalities has already been established as the treatment of choice for SVMs. This study confirms the reliability and safety of this, now widely applied, laser light. In view of the effectiveness of FLPDL in the management of ulcerated hemangiomas, it appears that this laser accelerates the healing rate of the lesion and thus reduces the discomfort caused by ulceration in a short period of time.

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