Evaluation of Port Wine Stains by Laser Doppler Perfusion Imaging and Reflectance Photometry before and after Pulsed Dye Laser Treatment*

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Treatment of choice for congenital capillary malformations of the port wine stain type is presently the pulsed dye laser. Although treatment results have usually been excellent or good, a few patients respond less well. Looking for a tool to predict and monitor the treatment we used laser Doppler perfusion imaging and reflectance photometry. Measurements with laser Doppler perfusion imaging were performed in 19 patients initially and after 1–3 treatments and with reflectance photometry initially and after 1–6 treatments. Before treatment, 15 of the patients had an increased bloodflow within the port wine stain in comparison with normal contralateral skin. After the laser treatments, 15 of 18 patients had decreased bloodflow within the lesion and all 18 had surrounding hyperemia. Reflectance photometry showed a successive increase in blanching and predicted within 6 weeks of the first treatment the eventual clinical result. The bloodflow, as measured with laser Doppler perfusion imaging, did not correlate well with the photometrically registered erythema. Reflectance photometry is a useful objective tool, which early in the treatment course indicates whether laser therapy will be successful. Laser Doppler perfusion imaging is less helpful in monitoring patients but may be of use in the study of port wine stain pathophysiology.

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Since the late eighties the flashlamp-pumped pulsed dye laser has been the treatment of choice for most congenital capillary malformations of the port wine stain type (PWS) in adults, children and infants (1). Numerous clinical studies have confirmed good to excellent results in most patients, with a very low incidence of scarring or pigmentary loss (2). It has been noted that the degree of response is dependent in some part on the anatomical location of the PWS. The midfacial portion of the cheek, the upper lip and the nose respond more slowly to treatment than other areas (3).

However, there is also a group of patients with congenital capillary malformations without arterio-venous or lymphatic components that are non-responders. These PWS are macular, rather deep pink coloured lesions with no sign of high flow vascularisation. Even after repeated laser treatments with high effect no blanching has been obtained.

Laser Doppler perfusion imaging (LDI), reflecting changes in bloodflow, has been used previously in the study of argon laser treatment of PWS (4). Reflectance photometry is another way of monitoring treatment as a function of erythema

following increased erythrocyte content (5). We here compare the results with these two techniques representing different vascular parameters.

MATERIAL AND METHODS

Patients

Nineteen Caucasian patients (11 females and 8 males) with congenital capillary malformations mainly of the face and neck were studied (Table I). Three patients had undergone treatment earlier with either argon laser or phosphor radiation, but not at the site treated in this study. The age of the patients ranged from 12 to 46 years, with a mean of 28 years, and they were not suntanned.

Pulsed dye laser

A flashlamp-pumped pulsed dye laser (Candela SPTL-1, Candela Corp., Wayland, Mass., USA) with a wavelength of 585 nm and a pulse duration of 450 µs was used. This wave-length coincides well with the third absorption peak of oxyhemoglobin. The energy density used was 6.75 J/cm^2 and the spot diameter was 5 mm. No local anaesthesia was used. Occasionally 7.25 J/cm^2 was used at the second treatment session, if the treatment result was not satisfying. Between one and 3 treatments were performed at 6-week intervals during a period of 3 months.

Laser Doppler perfusion imaging (LDI)

Before and directly after each laser treatment two 4×4 cm well marked areas, of lesional and contralateral normal skin respectively, were measured with the LDI (PIM Laser Doppler Imager, Lisca Develop AB, Linköping, Sweden). This data acquisition and analysis system generates processes and displays colour-coded images of the tissue perfusion. The optical scanning procedure guides, with the help of mirrors, a low power He-Ne laser beam over the tissue by a maximum of 4.096 measurement sites. This procedure takes about 4.5 min. In the presence of red blood cells, at a depth of a few hundred microns, partially backscattered Doppler-broadened light is detected by a photodetector positioned in the scanner head (Fig. 1). The light intensity transforms through the photodetector into an electrical signal. This electrical signal is fed into a processor which generates an output signal proportional to the perfusion. The computer samples and stores each perfusion for further signal processing and data analysis. A colour-coded perfusion image can be displayed on a monitor (7). The red-orange colour represents a high bloodflow, green a medium bloodflow and the bluish dark colour a low bloodflow. A comparison to the control side was made, where + + was a much higher bloodflow on the treated side, + a higher and ± no difference. A parenthesis was added when the flow was on the border to the lower sign (Table I).

Reflection photometry

Immediately before the laser treatments triplicate reflectance measurements were performed with the photometer at 23–25°C room temperature, both of lesional and of contralateral normal skin. The instrument used was a handheld microprocessor controlled reflectance photometer with a digital read out (Dermaspectrometer, Cortex Technology, Hadsund, Denmark). Green and red light at 585 nm and 655 nm, respectively, is emitted and the instrument measures the amount of

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Table I. *The results of laser Doppler perfusion imaging (LDI) and reflectance photometry (erythema index) before the first laser treatment*

Treatment results are expressed as % blanching and number of treatment sessions. + + = much higher (bloodflow in comparison to the contralateral normal side), + = higher, + − = no difference, ( ) = on the border to the lower next sign. Clinical outcome after last treatment. E = excellent, G = good, F = fair, P = poor.

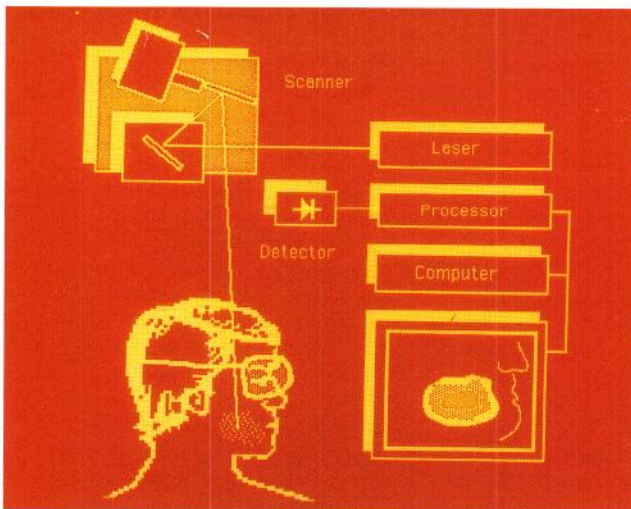| Location	LDI	Erythema index	% Blanching	Treatments	Clinical outcome
Cheek	+ +	13	54	4	F
Cheek	+ +	19		1	
Cheek	+ +	15	73	3	E
Upper hip	+(+)	15	7	5	P
Cheek	+	14	100	4	G
Neck	+	11		1	
Cheek	+	15	67	6	P
Cheek	+	10	60	6	G
Forehead	+	7	86	5	G
Neck	+	13	100	3	E
Neck	+	8	100	4	G
Cheek	+	13	62	5	G
Temple	+	5	80	1	E
Arm	(+)	26	46	3	P
Sternum	(+)	28	86	6	F
Thorax	+ −	2	100	4	F
Thigh	+ −	5	80	6	E
Breast	+ −	14	86	5	E
Neck	+ −	17	82	3	E

Fig. 1. The principles of laser Doppler perfusion imaging.

light reflected by the skin. The absorbance of the skin is registered as a read out of the erythema indices. For further details please see earlier studies (5, 8, 9).

The erythema index from the contralateral normal skin was subtracted from the erythema index from the PWS area before the relative blanching effect could be calculated. This relative blanching effect ranged from total (100%) blanching, when the treated PWS had returned to the same erythema index as the contralateral normal skin, to no (0%) blanching, when no change at all in redness of the PWS was noted after the treatment.

Statistics

The Spearman rank correlation test was used for the statistical evaluation.

RESULTS

Using the LDI technique, 15 out of 19 patients had higher blood perfusion in the PWS in comparison with normal contralateral skin before treatment. The remaining 4 PWS did not differ from normal skin (Table I and Figs. 2 and 3).

Directly after the first laser treatment 15 out of 18 patients had decreased perfusion, one had no change and 2 had increased bloodflow. All 18 patients showed hyperemia around the treated area, even when the surrounding area consisted of PWS skin. One patient's LDI registration was lost due to a technical error.

Before the second treatment 7 out of 14 patients, who could be measured with LDI, had a decreased perfusion in their PWS compared with the initial value. Five of the remaining 7 PWS had no change in their bloodflow. The last 2 had increased their PWS perfusion.

About 6 weeks after the second laser treatment 10 out of 14 had further decreased their perfusion, 2 had no change and 2 had increased their perfusion. All patients had peripheral hyperemia.

After the fourth or fifth laser treatment many patients had a reactive erythema, which often persisted for several months. Therefore, we preferred to postpone further treatments at least 12 weeks until this erythema was gone.

Reflectance photometry demonstrated a gradually decreasing erythema index along with the treatment sessions. Erythema was measured as the difference in reflectance photometry between the PWS area and the normal contralateral skin initially and before the last treatment (Table I). The average relative blanching effect achieved was 74%. There was no correlation between bloodflow and erythema ($r = 0.16$).

Clinical outcome after the last treatment was evaluated by the physician alone with the help of pretreatment photos. Two

Fig. 2. Port wine stains on right cheek before (*left*) and after (*right*) 4 pulsed dye laser treatments.

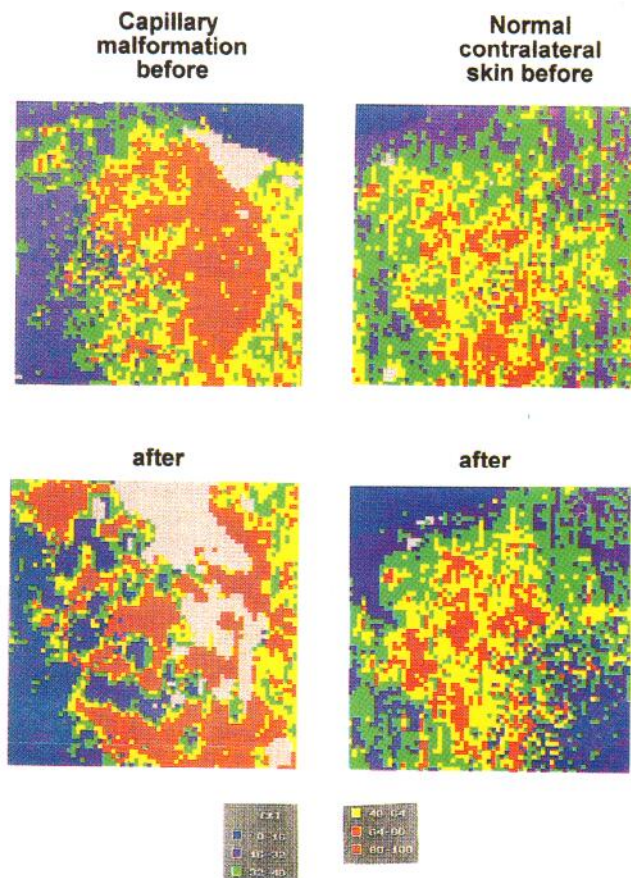## LASER DOPPLER IMAGER PULSED DYE LASER

Fig. 3. Laser Doppler perfusion imaging before and directly after pulsed dye laser treatment of the right cheek, in comparison with the left untreated cheek. (Same patient as in Fig. 2). The grey colour is caused by high light absorption of the blue discoloration after the treatment (see Discussion).

patients did not turn up for the second visit for social reasons (Table I).

Seven of the patients were smokers, but there were no significant differences between these and the non-smokers directly after the treatment according to the reflectance photometry measurements.

DISCUSSION

Laser treatment allows a selective photothermolysis, with specific damage to superficial cutaneous blood vessels. The depth of penetration is about 1.2 mm (10). Following treatment superficial blood vessels show agglutinated blood cells, fibrin, and platelet thrombi confined to the papillary and reticular dermis, with little or no damage to the surrounding adnexa. Sequential biopsy specimens have shown destruction of abnormally ectatic vessels with replacement by normal-appearing new vessels with little or no dermal scarring in 1 month (11).

The microvascular blood flow in PWS has been studied by means of several methods over the last decades (4, 12). Many of these techniques influenced the vasculature because they were traumatizing to the skin (13). Even very slight external stimuli such as pressure or mechanical contact may disturb the flow conditions of the microvascular bed under study. It is therefore important to use non-invasive methods. The LDI used in this study is a novel non-invasive method for mapping tissue perfusion. No physical contact between the scanning device and the tissue is necessary, and there is no discomfort for the patient. This device is a modification of an LDI instrument used in an earlier study, where we found that only 4 out of 13 patients with PWS had an increased perfusion compared to surrounding normal skin before treatment (4). This indicated that the red colour of the PWS does not necessarily have to correspond to a high perfusion but could reflect only an increased number of ectatic vessels. In our present study we did not find a correlation between bloodflow and erythema (Table I). A stimulus which produces hyperemia will not necessarily produce erythema, and erythema can develop without an increase of the bloodflow (14).

In the present study we noted that 15 out of 19 patients

had increased perfusion in comparison with normal contralateral skin. The remaining 4 patients had almost the same perfusion as in normal skin, and these PWS were situated on the breast, neck and thigh, while all the 15 PWS with increased perfusion were situated in the face. It is technically more difficult with this device to measure the blood perfusion of the thigh than the perfusion of the face. According to earlier studies, the skin microcirculation of the lower extremity decreases after lowering the leg (15), but in our study all the patients were measured in the horizontal position.

After the treatments small islands of either increased or decreased perfusion were often seen with LDI. This could be explained by non-homogenous laser therapy leaving untreated areas, or by the presence of normal vessels within the PWS area. These small areas with normal vessels are not treated and they respond with dilatation and hyperemia. Another point to consider is that PWS vessels in mid- and deep dermis have a defective innervation (16). Two patients had an increased bloodflow directly after the laser treatments. One had a lesion on the thigh and one on the cheek. The latter had earlier been treated with dermabrasion and cryosurgery. Both these patients responded excellently clinically to the treatments.

The blood perfusion of normal skin varies depending on the anatomical location. High perfusion is found e.g. in the face, especially in the medial parts. Centrofacial lesions and lesions involving dermatome V_2 in adults and children respond less favourably than lesions located elsewhere on the head and neck (3).

Before the second treatment, 5 patients had no change in their bloodflow compared to pre-treatment. This could be explained by the fact that vessels deeper than 1.2 mm from the dermo-epidermal junction are probably not reached by the dye laser radiation (10, 17), and vessels wider than 0.2 mm will probably not be effectively coagulated with the characteristics of our laser (18). Revascularisation from deeper vessels could then be a possibility. Two patients had increased their PWS perfusion compared to baseline, and this could be due to revascularisation with normal, not ectatic vessels. Within the lesion, however, the vessels vary in calibre and with age become more ectatic and slightly hypertrophic.

The LDI image registered immediately after laser treatment sometimes showed grey areas due to increased light absorption from the laser-induced bluish coloration of the skin. This could slightly enhance the reduced flow measured directly after laser therapy with the LDI instrument.

The relative blanching percentage in this study is comparable to an earlier report (5). The clinical results correlated well with the reflectance photometry measurements, as was recently shown (5).

LDI is a non-invasive method for mapping tissue perfusion. Bloodflow and erythema do not correlate well, however, indicating that for clinical, predictive purposes, erythema measurements with e.g. spectrophotometry may be more useful than measurements of bloodflow. Reflectance photometry is a sensitive technique for measuring erythema, according to earlier studies (5, 19). The size and the depth of the telangiectasias probably decide the therapeutic outcome with this type of laser.

ACKNOWLEDGEMENTS

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