Acta Derm Venereol (Stockh) 1992; 72: 6–10

Evaluation of Port Wine Stain Perfusion by Laser Doppler Imaging and Thermography Before and After Argon Laser Treatment*

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Thirteen patients with port wine stains (PWS) were treated with argon laser therapy. Before and at different points in time following treatment, skin blood perfusion and temperature were mapped with laser Doppler imaging and thermography. In nine patients no elevation in blood perfusion was observed in the PWS in comparison with the surrounding normal skin before treatment. In the remaining four patients a significantly ($p < 0.01$) higher blood flow was recorded within the PWS. Immediately after treatment nine patients showed elevated perfusion within the PWS. During the first two days following treatment, all patients showed a gradually decreasing hyperperfusion in the borderline between the PWS lesion and surrounding skin.

Immediately after treatment 10 patients had a significantly ($p < 0.01$) higher temperature in the PWS than in normal skin. During the first 24 h following treatment, an elevated perfusion was in general accompanied by a tissue temperature increase. Three and a half months after argon laser treatment, three patients showed excellent clinical results with no remaining PWS spots or scarring. Two of these patients had had both elevated perfusion and temperature in the PWS prior to treatment. ***Key words: Port wine stain; Argon laser; Laser Doppler imager; Thermography.***

(Accepted July 15, 1991.)

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Port wine stains (PWS) are congenital capillary telangiectasias (1, 2) which were treated with multiple therapeutic modalities including cosmetics, surgery, ultraviolet radiation, dermabrasion and tattooing before argon laser therapy was introduced in the sixties (3). Therapeutic success utilizing argon lasers has, however, varied (4). Best results have been obtained with darker lesions, especially in the face and in elderly patients (4). The treatment is time-consuming and may, unless carefully planned and performed, cause severe scarring. It is therefore of paramount importance to find predictive methods that allow optimal selection of patients for argon laser therapy.

Apfelberg et al. (5) studied blood perfusion in PWS patients with laser Doppler flowmetry, but were unable to predict the outcome of argon laser treatment. The difficulties may be attributed to the fact that the laser Doppler flowmeter gives information about tissue perfusion in only a single point, while the vascular architecture of PWS varies greatly even within the same area (6). In order to overcome this limitation of laser Doppler flowmetry, Nilsson et al. (7) developed a laser Doppler imager that creates an image of tissue perfusion. The method is based on the recording of Doppler shifts caused by movements of blood cells in the backscattered light of a laser beam that successively scans a certain tissue area.

The objective of this study was to investigate the perfusion status of PWS with a laser Doppler imager immediately before and at different points in time after argon laser treatment. Since thermography is considered useful in the prognosis of the outcome of argon laser therapy of PWS, it was included as a reference method (8).

MATERIAL AND METHODS

Patients

Thirteen patients (9 females) with PWS of various extents on different parts of the body were included in the study. All lesions were congenital and only one had been treated before. The age of the patients ranged from 17 to 65 years, with a mean of 29 years. Patient data and PWS sites are listed in Table I.

Argon laser

An argon laser (type Coherent Model 910) was used for treatment of the PWS. This laser emits light in the spectral range 488 to 514 nm. The light is guided through an optical fiber from the laser tube to a hand-held treatment head, producing a 1.5-mm wide beam (9). A 0.5-sec pulse duration was used with a mean power of 1.5W. According to earlier experiences this would give minimal risk of scarring.

In the skin, the light is absorbed mainly by melanin in the epidermal layer and by hemoglobin molecules in the red blood cells. The latter effect generates a certain amount of heat that coagulates and bleaches the tissue (10).

Laser Doppler imager

During the scanning procedure, the patient with PWS tissue is positioned between 12 and 20 cm under the laser Doppler imager (Fig. 1). Light from a 3-mW He-Ne laser is scattered onto the tissue by an optical mirror system. The 0.8-mm diameter light beam is moved step by step over the object, penetrating the tissue to a depth of a few hundred microns (11). In the presence of moving blood cells a fraction of the backscattered and Doppler-broadened light is received by a photodetector and converted into an electrical signal. This signal is further processed to scale linearly with blood flow (11) and eventually used as an estimator of perfusion. The scanning procedure and sampling by the perfusion estimator at each site of measurement is controlled by an AT IBM-compatible personal computer (Copam 386 SXB).

The complete scanning procedure requires about 4 min, during which time the light in the room is switched off in order to eliminate optical interference from the lighting with the Doppler signal. When all data are gathered, a colour-coded image showing spatial distribution of the tissue perfusion is generated on the monitor. Each of the six colours in the image corresponds to a certain interval of perfusion

*Presented at the annual meeting of the Swedish Society of Medicine, Stockholm, Dec 7, 1990.

Table I. *Patient data*

Pat No	Sex	Age	Site
1	F	23	Back
2	F	67	Forehead
3	F	19	Cheek
4	F	23	Cheek
5	F	20	Thigh
6	M	19	Neck
7	F	22	Shoulder
8	M	20	Cheek
9	M	16	Neck
10	F	18	Thigh
11	F	16	Arm
12	M	53	Cheek
13	F	34	Forehead

level. Black indicates low or zero perfusion, while highly perfused areas are coded in red. In order to be able to make comparisons between different images, the highest perfusion value in a series of images is used as a reference, and all perfusion values in the whole series are scaled in relation to this reference value. For the record, the images are put into a colour plotter (HP Paint Jet).

To compare the perfusion in normal skin with that in the PWS, the following statistical method was used. Two areas, one on normal skin and one on a PWS, were marked with a cursor. Each of the areas contained between 30 and 70 measurement sites. The samples were considered normally distributed. Mean perfusion and standard deviation were used to test the null hypothesis: the perfusion within the marked areas is identical. The level of significance was two-tailed and set to p-values < 0.01 in all cases.

Thermography

Skin temperature was measured in centigrades (°C) using a realtime thermal imaging system (Thermovision 870, Agema Infrared systems AB, Stockholm, Sweden). The detector is thermo-electrically cooled and the system operates in the short-wave band between 2 and 5.6 µm. Infrared radiation emitted by the object is converted into an electrical video-signal by the scanning unit. The inaccuracy of the system is limited to ± 0.1 °C. A graphic plotter provides colour images showing temperature changes with 16 colours, with black indicating the lowest temperature and white the highest.

The mean value of skin temperature was calculated and compared

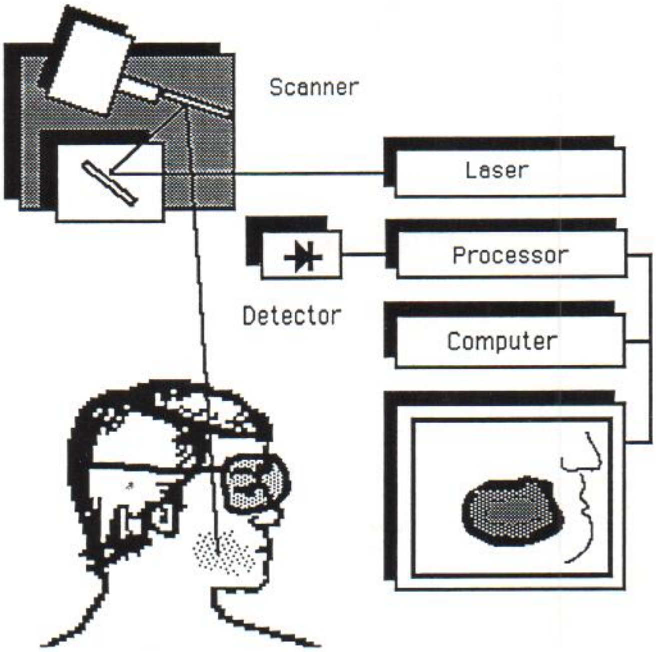

Fig. 1. Block diagram of the laser Doppler imager.

to that of the corresponding reference area on normal skin. To compare the temperature in normal skin with the temperature in the PWS, the same statistical method was used as for Laser Doppler imaging (LDI).

Procedure

LDI and thermography of the PWS were performed immediately before and about 15 min, 24 h, 48 h and three and a half months after argon laser therapy. Before measuring a metallic reflector was positioned around the PWS lesion in order to facilitate identification of the boundaries of the lesion on the laser Doppler image and thermogram. On each occasion a photographic documentation of the lesion was made and the ambient temperature recorded.

After the first measurements were made, the patient was brought to the treatment room and argon laser therapy initiated. Local anaesthesia was applied (prilocain hydrochloride, 10 mg/ml without epinephrine). The average extension of the treated areas was 8 cm^2. Within 10 min after the treatment a second laser Doppler image followed by a thermogram was recorded in the temperature-controlled room. The

Table II. *Perfusion (Pe) and temperature(T) in PWS compared to surrounding normal skin,before and after treatment*

Pat.	Before		After		24h		48h		3.5mo		Clinical results	
No	Pe	T	Pe	T	Pe	T	Pe	T	Pe	T	3.5 mo	7 mo
1	0	0	+	+	+	+	+	0	0	0	M	M
2	+	+	+	+	+	+	0	+	+	0	E	E
3	0	0	0	+	0	+	0	+	0	0	G	G
4	0	0	–	+	–	+	–	0	+	0	E	E
5	0	0	+	+	+	+	+	+	0	0	U	/
6	+	0	+	0	0	0	0	0	/	/	/	M
7	0	0	+	+	+	0	0	0	/	/	/	G
8	0	0	–	0	blister	blister			0	0	M	G
9	+	0	0	0	0	0	+	0	+	0	U	U
10	0	0	+	+	+	+	+	0	+	0	G	E
11	0	0	+	+	+	+	0	+	0	0	M	M
12	+	+	+	+	+	+	+	+	+	+	E	E
13	0	0	+	+	0	0	0	0	/	/	G	E

0 = no significant difference; + = higher perfusion/temperature in the PWS, $p < 0{,}01$; – = lower perfusion in the PWS, $p < 0{,}01$; / = patient not available for study; E = excellent; G = good; M = moderat; U = unchanged

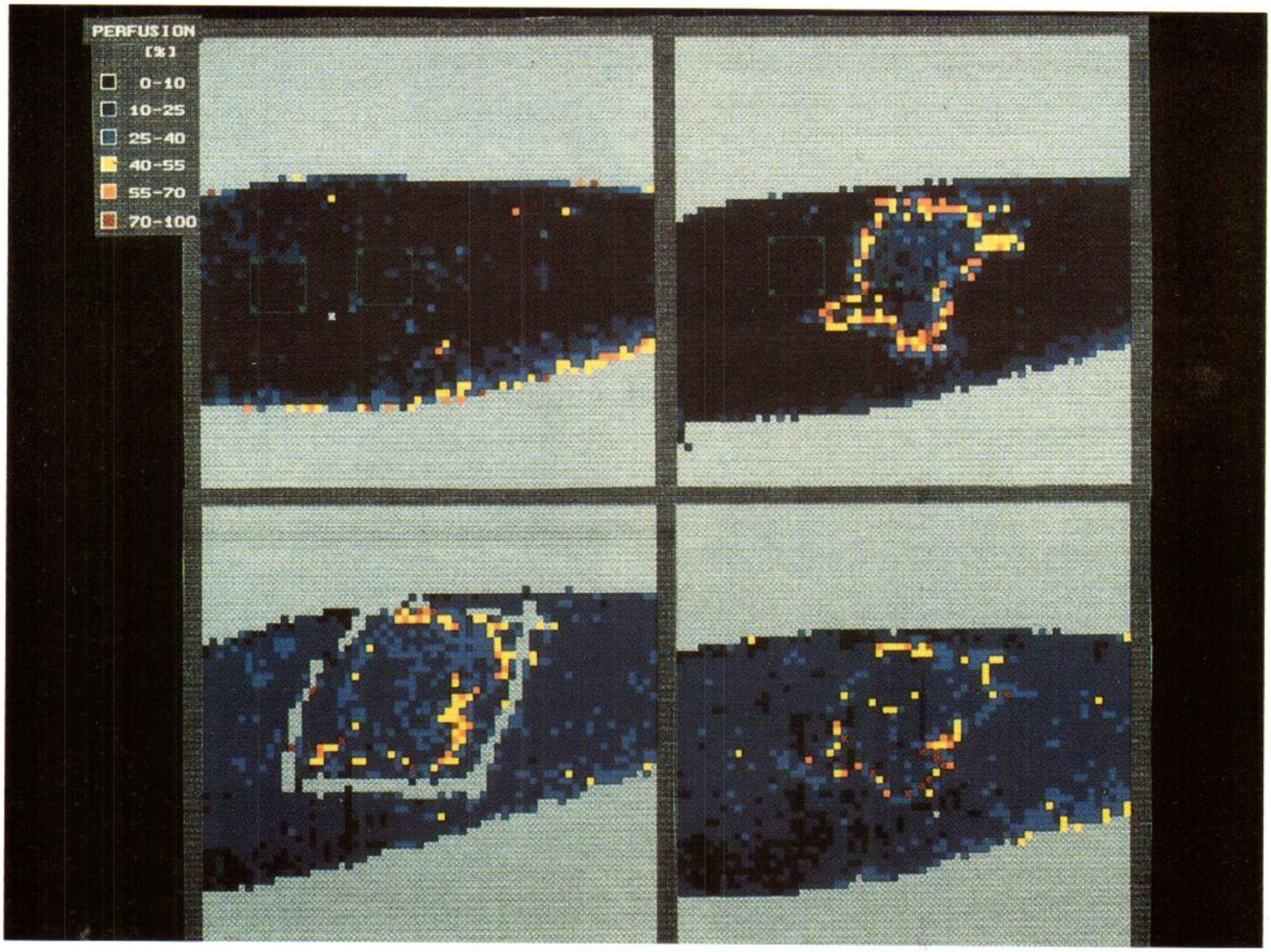

Fig. 2. Perfusion images, from left to right; *a*) before treatment, *b*) directly after treatment, *c*) 24 h after treatment and *d*) 48 h after treatment. The areas marked in green are used for statistics.

ambient temperature was kept within 22.0 ± 1.4°C during all measurement procedures.

In association with the measurements performed three and a half months after treatment, a judgement of the results was made in collaboration with the patient. The results were classified as *excellent, good, moderate* or *unchanged*.

RESULTS

Laser Doppler imaging

Before treatment, LDI did not show any difference between perfusion levels within the PWS and in the surrounding unaffected skin in 9 out of 13 patients (Table II). In the remaining four patients, significantly elevated perfusion was observed within the PWS lesions. In patient No. 12, who was earlier treated with electrocoagulation, high perfusion values were observed in regard to spots within the PWS.

After treatment, all patients showed pronounced hyperemia in the borderline between the PWS and surrounding skin. In 11 patients perfusion in the centre of the PWS was significantly different from that of normal skin. In 2 of these patients (No. 4 and 8) reduced perfusion was observed. In the remaining 9 patients elevated perfusion was recorded.

After 24 and 48 h there was a gradual reduction of perfusion in the borderline between the PWS and surrounding tissue. At these points in time an elevation of perfusion in the centre of the PWS was observed in 7 (after 24 h) and 5 (after 48 h) patients, respectively. One patient (No. 4) still showed significantly lower perfusion in the PWS both 24 and 48 h after treatment.

After three and a half months, reactive hyperemia in the borderline between the PWS and surrounding skin had disappeared, and perfusion returned to baseline levels in all patients. In 5 out 10 patients, however, a blanched PWS and higher perfusion was now observed within the treated area in comparison with the surrounding skin.

Fig. 2 shows examples of perfusion images, before and after treatment for patient No. 11. In the image taken immediately after treatment, the hyperemic zone is clearly seen, as well as higher perfusion in the treated area. The areas used for statistics are marked with a green border.

Thermography

Before treatment only 2 patients (Nos. 2 and 12) showed higher temperature within the PWS as compared to surrounding tissue (Table II). Eight patients showed a measurable rise in PWS temperature after argon laser treatment. The average temperature increase was 1.9 ± 1.6 °C. The PWS that had a higher temperature from the start (Nos. 2 and 12) did show an average temperature increase of 0.7 ± 0.3 °C. Immediately after the treatment all 10 patients had higher temperature in the PWS area than in normal skin. At the 24- and 48-hour measurements the elevated temperature slowly decreased, but a return to pretreatment levels was observed only in measurements made after three and a half months.

Clinical results

Three and a half months after argon laser treatment, three patients (see Table II) showed *excellent* results with no PWS spots left and no scarring. Three patients showed *good*, three patients *moderate* results and two patient were almost *unchanged*. Two patients were not followed up at the three and a half month control. No patient showed scarring in the treated PWS area. After seven months a slight progress in blanching was seen in all patients who were followed up. This was expected according to earlier experiences and literature (3). Two of the patients with excellent results (Nos. 2 and 12) showed high tissue perfusion in the PWS, as manifested with both LDI and thermography prior to treatment.

DISCUSSION

The main abnormalities characterising PWS are vascular ectasia and a substantial increase in the number of vessels.The vessels in mid and deep dermis have a defect innervation which may be of importance for the developement of the disease (12). Mean vessel depth within the PWS is 0.46 ± 0.17 mm and vessel density is highest in the immediate subepidermal area(13). Age correlates well with both progressive vessel ectasia and colour shifts from pink to purple (13). In healthy skin the argon laser beam penetrates the tissue to a depth of about 1 mm (14), while the scanning He-Ne laser beam in the LDI device has a median measuring depth of about 0.2 mm (15). The depth of the argon laser beam is dependent on the amount of melanin in tissue and to some extent on erythrocyte concentration (10). Thus, the majority of ectatic vessels and the thermal energy delivered by the argon laser beam and the peak sensitivity of the laser Doppler imager are all confined to the upper 1 mm layer of the skin.

Thermography (8), transcutaneous microscopy (16), reflectance spectrophotometry (17) and laser Doppler flowmetry (18, 19) are examples of non-invasive methods used earlier in the assessment of argon laser treatment of PWS. Generally, large differences between measurement results obtained from the PWS area in comparison with normal skin correctly predicted a favourable outcome of argon laser therapy (20). This is in accordance with the results obtained in this study, where two (Nos. 2 and 12) out of the four patients with excellent results had both elevated tissue perfusion and temperature within the PWS area. These two patients were older than the others (67 and 53 years, respectively) and their PWS were purple in colour and located on the face. Elevated perfusion prior to treatment was also found in two patients (Nos. 6 and 9) with only moderate and unchanged clinical results. These two patients were, however, younger (19 and 16 years, respectively) and their PWS were not purple colour.

All patients had increased perfusion in the border between the PWS and healthy skin tissue directly after treatment as measured with LDI. The hyperemia, which was interpreted as a normal reaction to heat stimuli in healthy skin, diminished gradually during the following two days and had disappeared completely three and a half months later. The increased blood flow seen in the centre of the lesion in the majority of the patients directly after argon laser treatment was more surprising, because immediate coagulation of the vessels would have been expected. The phenomenon may be explained by the fact that although the median measuring depth of LDI is about 0.2 mm, sensitivity to perfusion throughout a deeper microvascular network is still significant (15). If this deeper network is thermally stimulated rather than coagulated by the argon laser beam, an increase in perfusion, that will give a substantial contribution to the recorded Doppler signal may be expected. In addition, increased perfusion in the deeper dermis could be due to the inflammatory response. In either case the reaction may be the cause of the persistent elevation in PWS area temperature that was frequently observed after treatment. During the first 24 h after treatment elevated perfusion was accompanied by a tissue temperature increase in 14 out of 16 measurements.

In conclusion, this study shows that in only 4 out of 13 patients was the perfusion higher in the PWS than in the surrounding normal skin before treatment. After treatment a parallel elevation of perfusion and temperature within the PWS area was in general observed. The results indicate that neither the LDI technique nor thermography can unambiguously predict the clinical results of argon laser treatment of PWS. Both methods may yet be useful tools in the further understanding of the pathophysiology of PWS.

ACKNOWLEDGEMENTS

The authors gratefully thank Dr. Henry Svensson for initiating the LDI part of the study and Dr. Magnus Åberg for fruitful discussions. We also thank Agema Infrared Systems AB, Stockholm, Sweden, for the use of Thermovision 870.

This study was supported by the Edvard Welander Foundation and the Swedish National Board of Technical Development (90–01486P).

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