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Treatment of portwine stains using the pulsed dye laser

W. H. Reid, I. D. Miller, M. J. Murphy, B. McKibben and J. P. Paul

Plastic Surgery Unit, Canniesburn Hospital, Glasgow, and Bioengineering Unit, University of Strathclyde, Glasgow, UK

SUMMARY. **Five years of clinical experience of the treatment of portwine stains using the flashlamp-pumped dye laser is presented.**

The dye laser, when turned to a wavelength of 577 nanometres with a short pulsewidth of the order of 340 microseconds, may be used to target selectively the dilated vasculature constituting the lesion.

Patients with ages ranging from 5–45 years were treated under general anaesthetic using a computer controlled scanning system developed by the authors.

Several repeat treatments were found to be necessary. Results are presented ranging from total eradication of the lesion to marginal lightening only. No scarring of the treated sites was evident.

In recent years, many workers have described the application of laser technology to the treatment of portwine stains. Lasers have been used to target specifically the oxy-haemoglobin encapsulated within the dilated vasculature constituting the lesion. In this context, continuous wave argon and dye lasers, in addition to pulsed dye and copper vapour lasers, have received attention.

Laser treatment of portwine stains dates to first reports by Apfelberg *et al.* (1976) who described the application of the argon laser to the management of vascular lesions. A later report, by Dixon *et al.* (1984), detailed a study of 146 patients using the argon laser. Results demonstrated a higher incidence of scarring of 40% among young patients, compared to a 20% incidence of scarring in adult patients.

The argon laser wavelength of 514 nm does not coincide precisely with the absorption maxima of the targeted oxy-haemoglobin. Three such absorption maxima exist, at 418 nm, 542 nm and 577 nm. Highest blood absorption is exhibited at 418 nm, a wavelength at which the melanin in the epidermis displays significant absorption. Competitive epidermal absorption decreases through the visible region to the 577 nm wavelength, which has consequently been the subject of more recent study.

The identification of the optimal 577 nm wavelength was accompanied by studies of the effect of the exposure duration on the efficacy of treatment. Anderson and Parrish (1981) described the requirement for the impartation of the energy within the thermal retention time constant of the targeted vasculature. These parallel studies prompted the development of the flashlamp-pumped tunable dye laser. The use of a short-pulse (0.3 microseconds) dye laser was first described by Greenwald *et al.* (1981). In that study, and later reports by Tan *et al.* (1984), the ability of the laser to produce purpura was noted, although neither group of workers was able to report favourable response to treatment.

An explanation for the lack of efficacy was advanced by Hulsbergen-Henning *et al.* (1984) who demonstrated the effects of the short pulse dye laser to include locally specific microvaporisation and mechanical damage to the vasculature. They showed that these processes constituted reversible damage mechanisms.

These findings prompted the redevelopment of a longer pulsewidth dye laser, thought more likely to induce coagulation and shrinkage of the targeted vasculature as a result of limited conduction of heat during the 340 microseconds pulsewidth, and this pulsewidth was thought more closely to approximate the thermal retention time constant of the targeted vasculature.

The efficacy of the longer pulse dye laser has been documented by Garden *et al.* (1988) who found, by direct comparison, a higher incidence of lesion lightening among patients treated with the longer pulse laser. This study documents the findings from a 5-year clinical trial of the use of the long pulse flashlamp-pumped dye laser. The treatments are based on extensive theoretical modelling of the interaction process (Miller *et al.*, 1991), and use a novel scanning system developed by the authors.

Materials and methods

A flashlamp-pumped dye laser (Candela Corporation, US) was used in these trials. This laser emitted pulse energies of up to 5J with pulsewidth of 340 microseconds. The laser was sited remotely from the treatment area, energy being delivered by means of a 1 mm diameter optical fibre. The laser light was launched into the fibre using a 5 cm focal length lens and was collected at the distal end by means of a 1.8 cm focal length lens contained in the endpiece.

A computer controlled scanning assembly designed by the authors controlled the movement of the endpiece over the area to be treated. A mechanical

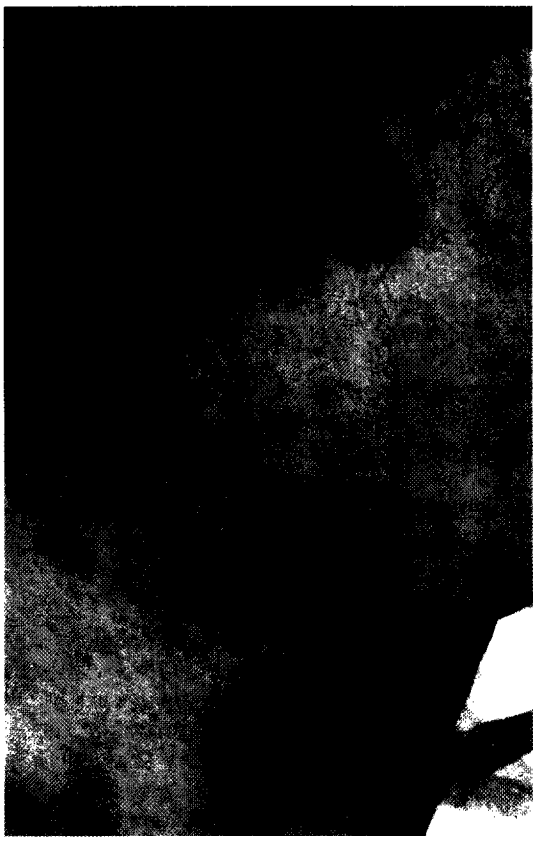

Fig. 1

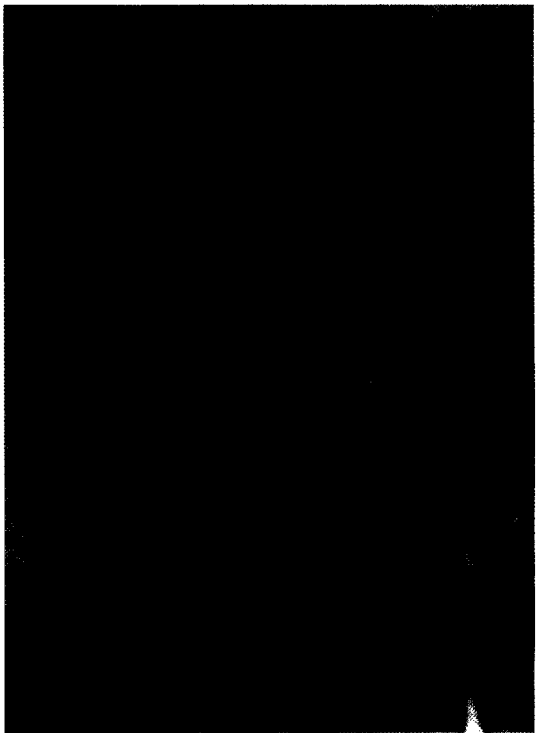

Fig. 2

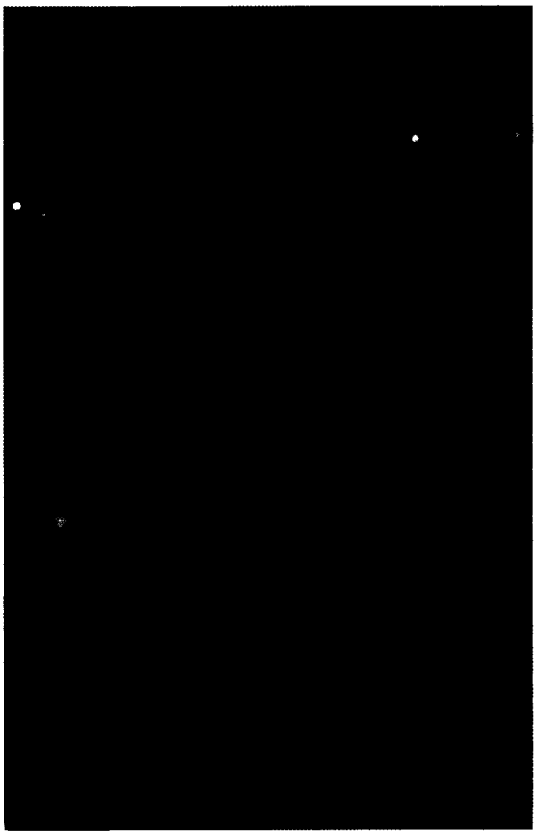

Fig. 3

Fig. 4

Figure 1—Lesions on the neck before treatment. **Figure 2**—Lesions after application of 4 full area treatments. **Figure 3**—Faint facial lesion before treatment. **Figure 4**—Lesion after application of 3 full area treatments.

scanning rig manoeuvred the endpiece in two dimensions via stepper motors interfaced to the computer by an Amplicon PC14 (a card and associated circuitry). The software was written in Turbo Pascal 5.5. This was flexible to allow various parameters, such as spot size, distance and delay between spots to be input at the start of treatment. The spot diameter used in this study was 3 mm.

The system could be run in several modes. In the "outline" procedure, the surround of the stain to be treated was traced using the keyboard arrow keys. This moved the endpiece, which was followed on the skin surface by the movement of the visible He/Ne aiming beam. The computer mapped the area thus delineated and upon instruction the laser energy was deposited in continuous, hexagonally placed shots. The system was also used in a "manual" mode where the clinician simply moved the endpiece to the desired position with the arrow keys and pressed the designated key to fire the laser. This facility allowed small areas to be treated. The entire scanning rig could be tilted to cope with the contours of the face. This scanning system permitted the contiguous or overlapped placement of the laser spots over the lesion in a precise manner.

The laser pulse energy was measured by use of Scientech model 365 energy indicator with a black body response, giving +3% accuracy.

Subjects

128 treatments were administered to 25 patients over a 5-year period. During this period, technical difficulties with the laser resulted in less than 1–2 years operational time. In addition, due to the need for general anaesthesia, these sessions had to be incorporated in the hospital theatre list. The accommodation was for three patients to be treated per week. The patient age ranged from 5–45 years, with 20% in the < 12 year category, 56% in the 12–25 year category and 24% over 25 years old. Lesion type, sited on the head and neck regions, ranged from pale pink and flat to deep red and nodular.

Methods

Patients were photographed and placed under general anaesthesia to ensure a stable and immobile target site. Choice of laser energy was determined corresponding to the onset of immediate purpura followed by a delayed purpuric reaction, usually evident within several minutes. These observations have been linked to the induction of both coagulation and vaporisation of blood vessels below the treated site (Garden *et al.*, 1988). These requirements dictated the use of an energy density of 8–10 Jcm^{-2} on the skin, with a pulsewidth of 340 microseconds.

Patients were recalled at intervals of 4 weeks if possible, although many of the patients were treated at less regular intervals. Several repeat exposures were found to be necessary in all cases. The laser spots were scanned over the lesion under computer control over a grid within the area of the lesion. The spots were slightly overlapped to minimise inter-spot spacings corresponding to untreated areas.

Results

Clinical response was recorded after each exposure. The desired reaction included immediate, followed by further delayed, purpura sometimes lasting several days. Erythema was evident following treatment. Hypo-pigmentation, which did not persist, was evident among several patients.

The treatment response of a 19-year-old female patient is illustrated in Figures 1 and 2. The lesions were treated on 4 occasions with a mean spacing between treatments of 8 weeks.

The response of a 24-year-old female patient is shown in Figures 3 and 4. Here, a total of 3 treatments were administered.

The partial treatment of a 45-year-old female patient is shown in Figures 5 and 6. Here, the automatic scanning system was used to administer 2 treatments. The treated area, corresponding to the lightened scanning grid area, can be clearly seen in Figure 6.

The treatment of a 5-year-old male patient is shown in Figures 7 and 8. Two treatments were administered uniformly over the entire lesion.

Figures 9 and 10 illustrate the treatment of a 7-year-old female patient. Two treatments were administered uniformly over the affected sites.

Figures 11 and 12 illustrate the treatment of a 21-year-old female patient. The grid pattern associated with the use of the automatic scanning systems is apparent in Figure 12 which illustrates the appearance after 4 treatments had been administered.

The above results document the response of 6 of the 25 patients treated. Of the remainder, 5 patients displayed greater than 50% lesional lightening after 2–6 treatments, 3 patients exhibited between 25% and 50% lesional lightening after 1–6 treatments, while the remainder (11) demonstrated less than 25% lesional lightening after 1–6 treatments. One of these latter cases was a child of 9 years who had a very dark (although smooth) stain covering more than 50% of one side of the body, who exhibited less than 10% lesional lightening after 5 treatments. Excluding this case, the average lesional lightening for the under 12 year-old age group was 52% for 1–6 treatments. 45% of patients displayed in excess of 50% fading after a mean of 3.9 treatments, while a further 25% displayed 25–50% fading after a mean of 3.8 treatments. The remaining 14% displayed less than 25% fading after a mean of 4.33 treatments. 2 patients, both of age 45 years, presenting deep red lesions, displayed in excess of 50% lightening after only 2 treatments. Most of the patients are continuing to undergo treatment.

Discussion

The progressive ectasia of portwine stains has been noted (Barsky *et al.*, 1990) from infancy onwards. It has been suggested also that younger patients, presenting faint pink lesions, respond more favourably to

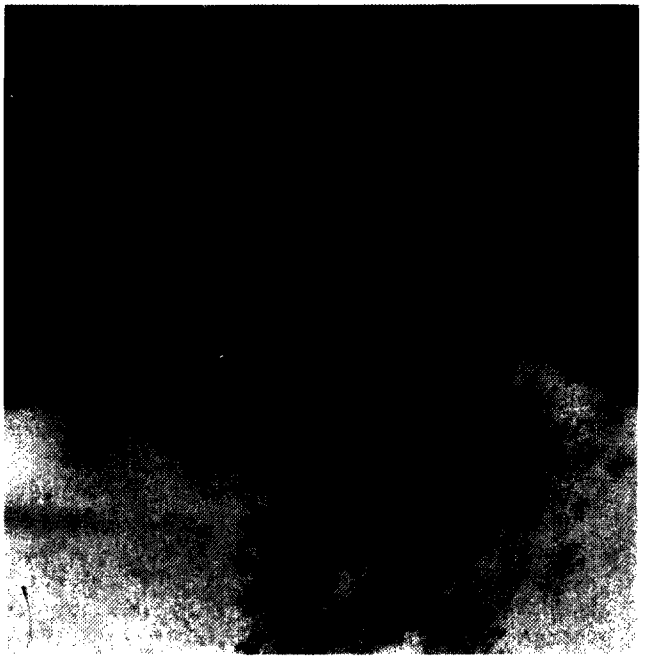

Fig. 5

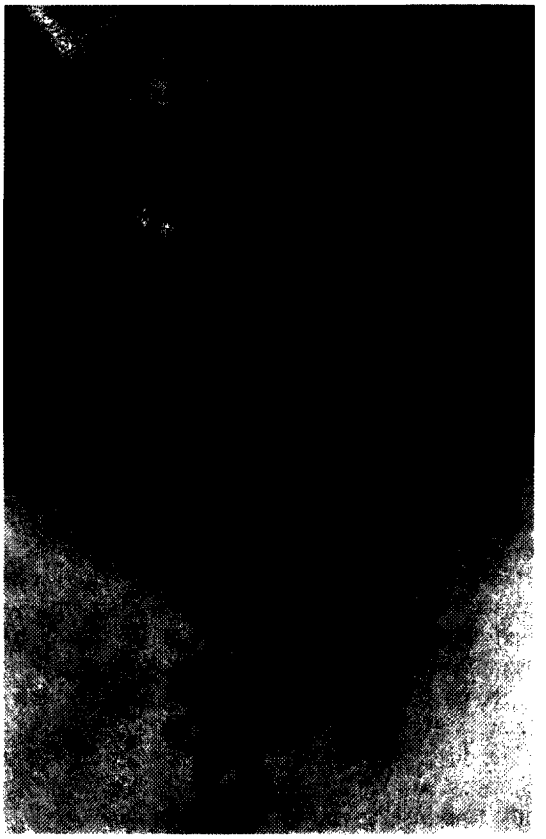

Fig. 6

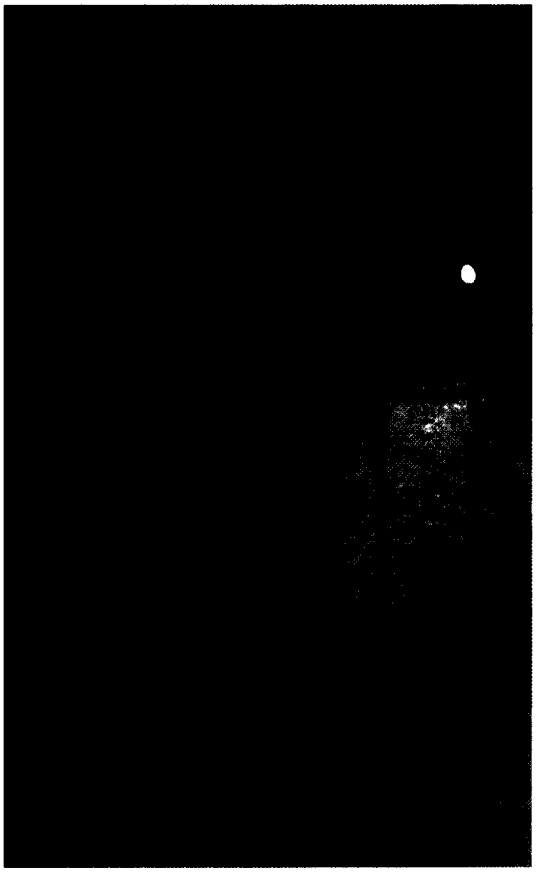

Fig. 7

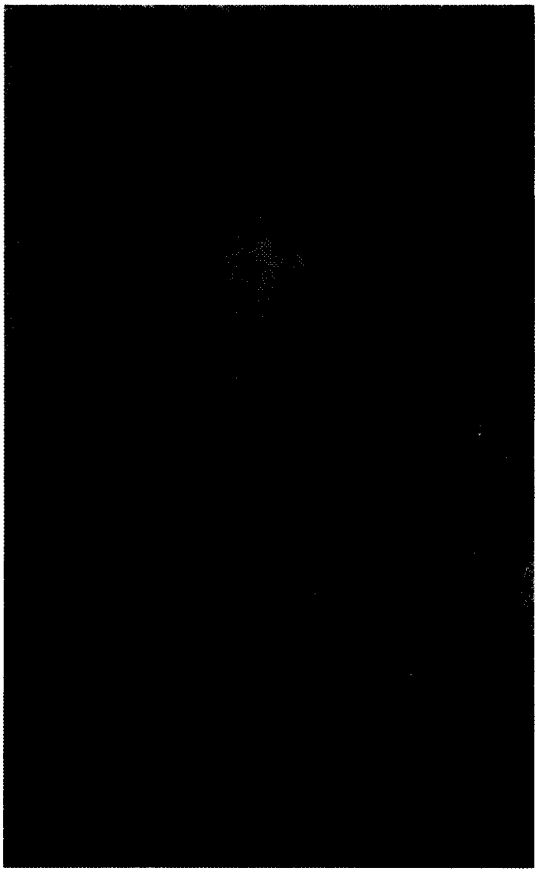

Fig. 8

Figure 5—Dark mature lesion before treatment. **Figure 6**—Lesion after application of 2 partial area treatments. **Figure 7**—Faint facial lesion before treatment. **Figure 8**—Lesion after application of 2 treatments.

Fig. 9

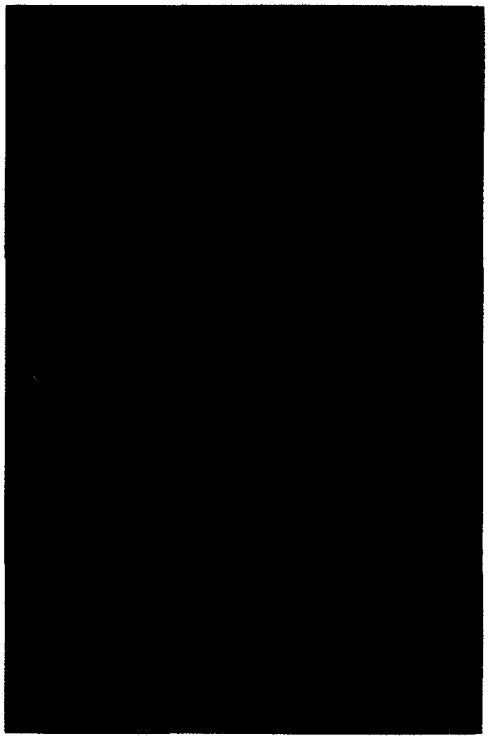

Fig. 10

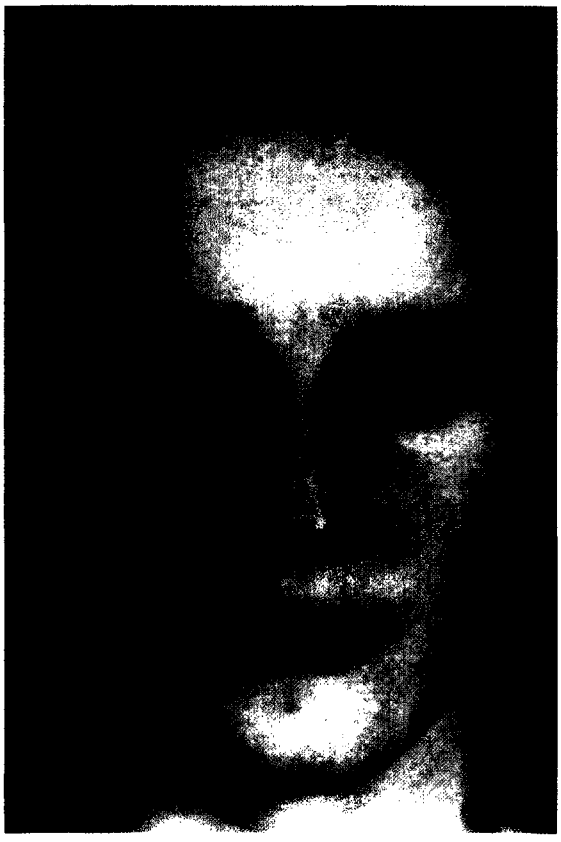

Fig. 11

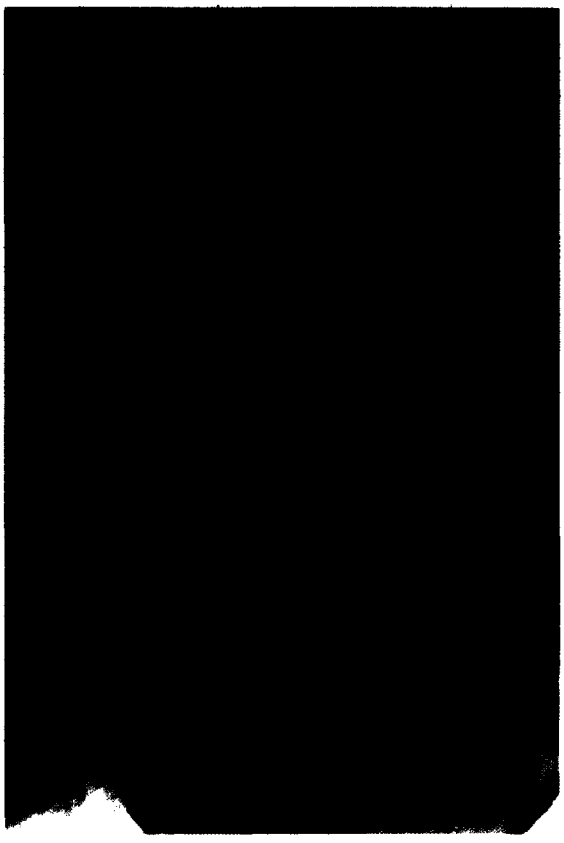

Fig. 12

Figure 9—Facial lesions before treatment. **Figure 10**—Lesions after application of 2 treatments. **Figure 11**—Facial lesions before treatment. **Figure 12**—Lesion after application of 4 treatments.

treatment (Garden *et al.*, 1988; Tan et al., 1989). Tan *et al.* (1989) reported that lesions overlying bony prominences responded more rapidly to treatment.

In this study, repeat applications were found to be necessary in all instances. This may be a consequence of the distribution of the vessels within the dermis. Although most vessels are found in the sub-papillary plexus, they may shadow deeper vessels extending to a full depth in excess of 1 mm (McLeod, 1984).

Response did not correlate well with age of patient or location of lesion. The youngest patients did not typically display the optimum response to treatment. These findings are not entirely in agreement with those reported by Tan *et al.* (1989), who described a lower required number of treatment sessions among the youngest children with the lightest lesions.

It was found that an inter-treatment spacing of 4 weeks was preferred, where possible. On each occasion, the entire area should be treated. Failure to treat portions of the lesion may permit regrowth of the dilated vasculature from neighbouring untreated sites. Equally, lengthy inter-treatment delays may permit a feeding from deep vasculature. This was suspected in the case of a 19-year-old male patient treated at mean intervals of 25 weeks who displayed a darkening of the treated area as a result of vascular regrowth.

The automatic scanning system designed by the authors ensured a very precise and uniform coverage with no untreated gaps in the stain. The scanning system allowed the laser to be used to its full potential without the additional need for the variance of applications from clinician to clinician to be taken into account.

It has been difficult to correlate response to nature of lesion as histology has not generally been available. A means of non-invasive monitoring would be highly desirable, enabling correlation of effect with the nature of the vasculature structures. In particular, a knowledge of depth, distribution and ectasia would be of relevance.

Although a significant lightening of colour has been demonstrated, it is felt that the inflexibility of this type of laser to respond to different target requirements may preclude its further widespread use. In particular, the pulsewidth may not be modified to correspond to the thermal requirements of the targeted vessels. In this regard, it is felt that lasers such as the copper vapour laser may supersede the use of the dye laser as they continue to demonstrate extended modes of operation. In particular, the variable laser parameters available and ever increasing power capabilities offer a flexibility not associated with the dye laser. Candela is currently marketing a dye laser with a 585 nm wavelength. Mathematical modelling carried out at the Bioengineering Unit, Glasgow, predicts that much higher fluences are necessary to produce purpuric reactions with this wavelength. This work will be considered in more detail in a later paper.

Acknowledgements

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The Authors

W. H. Reid, FRCS, Plastic Surgery Unit, Canniesburn Hospital, Bearsden, Glasgow G61 1QL

I. D. Miller, BSc, PhD, Bioengineering Unit, Wolfson Centre, University of Strathclyde, 106 Rottenrow, Glasgow G4 0NW and Derma-Lase Ltd.

M. J. Murphy, BSc, Bioengineering Unit and Derma-Lase Ltd.

B. McKibben, BSc, Bioengineering Unit, Wolfson Centre, University of Strathclyde.

J. P. Paul, BSc, PhD, Bioengineering Unit, Wolfson Centre, University of Strathclyde.

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