Initial Clinical Experience Using a Diode Laser in the Treatment of Retinal Vascular Disease

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Summary

A pilot study has been carried out to investigate the clinical use of an infrared diode laser in the treatment of a number of retinal vascular conditions. A hand-held device was employed initially and subsequently a further prototype was developed for use in conjunction with a standard slit lamp microscope.

Thirty-three eyes in thirty patients were treated for conditions such as proliferative diabetic retinopathy, exudative retinopathy and branch and central retinal vein thrombosis. Regression of neovascularisation was observed in 13 of 16 eyes (81%) with proliferative diabetic retinopathy and in six of eight eyes (75%) with branch retinal vein occlusion. Four eyes were successfully treated for established or incipient rubeosis iridis following central vein thrombosis. Focal photocoagulation applied to five eyes for diabetic exudative maculopathy resulted in partial resorption of the exudates. These results are presented together with information on the ease of use of the laser and its reliability. The implications of the development of this instrument in the context of its place in ophthalmic therapy are discussed.

Therapeutic retinal photocoagulation has been practised for over thirty years. The xenon arc photocoagulator developed by Meyer-Schwickerath provided a source of broad band optical radiation which was effective in producing full-thickness chorioretinal lesions[1]. The advent of the ruby laser in 1960[2] aroused interest amongst ophthalmologists and this rapidly resulted in the investigation of its potential in the treatment of ocular conditions. Early work on animals by Zaret in 1961[3] was followed within two years by therapeutic regimens in humans[4]. Although the ruby laser (emitting at 694.3nm) was relatively effective in producing chorioretinal adhesions in detachment surgery, results were disappointing in treating retinal vascular conditions[5,6]. In the mid-sixties the failure of the ruby laser was attributed to an inappropriate wavelength and the resultant lack of absorption of laser energy in retinal vessels. Recent work has emphasised the role of the retinal pigment epithelium in the treatment of retinal vascular diseases[33,34]. The pigment epithelium is a tissue with broad band absorption characteristics and the major site of energy degradation

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in retinal photocoagulation. The inadequacies of the ruby laser are now thought to be due to the pulse duration rather than wavelength as the short pulse duration of early instruments produced a high risk of choroidal haemorrhage.

L'Esperance investigated the clinical potential of the argon laser (488-515.5nm) in 1965[7], and it became commercially available in 1971. Numerous studies have demonstrated its efficacy in the treatment of common retinal conditions, for example proliferative diabetic retinopathy[8], forms of diabetic maculopathy[9] and the complications of retinal vein thrombosis[10]. In addition a number of trials have indicated early beneficial effects in the treatment of subretinal neovascular membranes, although longer term observations have demonstrated recurrence of membranes and visual deterioration[11-13].

In the mid-seventies a new red light emitting laser, the krypton laser (647nm) was introduced and found to be as effective as argon in the treatment of retinal conditions[14]. It also had advantages when compared with argon blue in that its longer wavelength resulted in virtually no absorption by macular xanthophyll pigment[15,16]. Further, the lower photon energy at longer wavelengths in the visible reduced the potential for inducing photochemical damage[17]. More recently, the continuous wave dye lasers have provided the facility to tune the wavelength of emission thus, in theory, allowing the possibility of selectively photocoagulating particular retinal structures. Current studies demonstrate that the thermal damage resulting from dye laser exposure is widespread throughout the outer retina and have failed to support the concept of selectivity of targets. Recent comparisons of the treatment of neovascular membranes with several dye laser wave lengths have not demonstrated any difference in clinical efficacy[18,19]

Continuous wave argon, krypton and dye lasers, while broadly similar in terms of both the damage they induce to the retina, and the therapeutic efficacy also have several inherent disadvantages. Laser energy is generated within a relatively bulky gas-filled tube; electrical energy consumption is high, and the efficiency of electrical-optical conversion is low. Many systems require a three-phase power supply, and forced cooling facilities dependent on circulating air or water. Heat dissipating factors tend to increase the size of the equipment and these together with their special electrical requirements mean that in most situations rooms need to be adapted for the permanent installation of laser apparatus. Additionally, maintenance costs are high with the average tube life being 2–3 years, and the cost of replacement about 20% of the total cost of the laser.

Advances in semi-conductor technology have allowed the development of infrared diode lasers (790–950nm) measuring a few millimetres in size. These are used in compact disc players and have important applications in the fields of optical printing and communications. The recent availability of laser diodes with an output power of 1–2 W has stimulated interest in their potential applications in ophthalmic surgery. As early as 1984 Pratesi postulated some of the possible uses of diode lasers in medicine. Such lasers had the theoretical advantages of being extremely compact, highly efficient and relatively inexpensive[20].

Brancato and Pratesi[21] and Puliafito[22] working independently successfully produced chorioretinal lesions in rabbit retinas with diode lasers. The former used a transpupillary route while the latter used an intraocular fibre optic. We published the first histopathological report of retinal photocoagulation by a diode laser in human eyes[23]. Microscopic analysis of the lesions demonstrated them to be similar to those produced by conventional clinical photocoagulators and in particular to those induced by krypton lasers. The physical parameters of the exposures such as power levels, exposure durations and spot sizes were also similar.

Encouraged by these promising early results, we have undertaken a limited clinical trial. Subsequent to ethical committee approval, a pilot study was initiated in order to investigate the therapeutic efficacy of the diode laser in the treatment of a number of common retinal vascular conditions. The further aims of the study were to collate information on a number of other important aspects of therapy, such as to monitor any

Fig. 1. *Hand-held version of diode laser, utilising a direct ophthalmoscope.*

ocular side effects; the subjective impressions of the patients treated with particular regard to discomfort during photocoagulation; to examine the ergonomic and physical aspects of the use of such a laser in a busy clinic; and to assess its reliability in repetitive and extensive use. This paper describes our early clinical experiences using the diode laser for retinal vascular problems in 30 patients.

Materials and Methods
Instruments
Throughout this study a Spectra Physics SDL2430 laser diode was used, with a spectral emission at 810nm and with a maximum output power of 800mW. The laser diode was driven by a Spectra Diode Labs SDL800M laser diode driver with pulse duration and amplitude controlled by an external pulse generator. Power and energy levels at the eye were calibrated with a UDTS390 photometer and referenced to an EG and G radiometer 581. The laser operates in a continuous mode but is a power on demand system.

Two forms of delivery system were employed, a hand-held version utilising a direct ophthalmoscope and a model which was attached to the tonometer stand of a standard Haag-Streit 900 slit lamp microscope (Figs 1 and 2). In the hand-held type the diverging beam produced by the diode was first collimated and then combined with a helium-neon beam to provide an aiming system. Illumination and viewing of the retina was facilitated by a modified direct ophthalmoscope with a conventional quartz halogen source. The laser spot size was 200 microns

and exposure durations of 0.25 and 0.5 seconds were selected.

In the slit lamp version an aiming beam was provided by a red-emitting (690nm) low power (300 microwatts) laser diode. Viewing of the retina was accomplished with the optics and illumination source of the slit lamp micro-
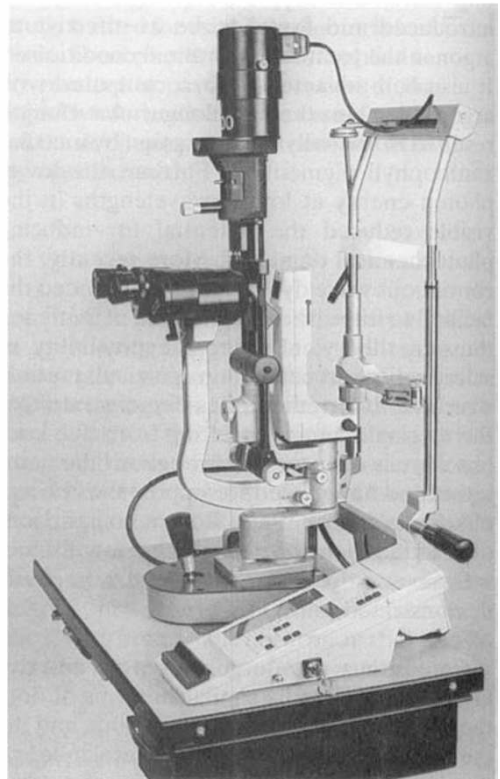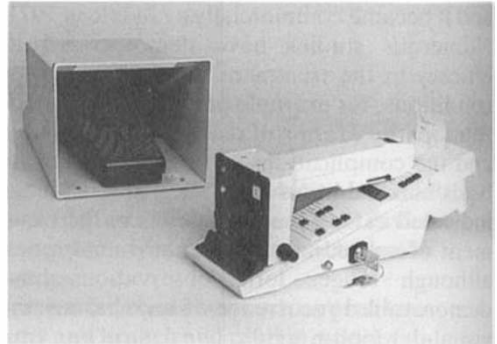

Fig. 2 *Top: Version of diode laser which is attachable to a standard slit lamp microscope, shown with instrument console and foot switch. Bottom: Diode laser shown mounted on Haag-Streit slit lamp microscope.*

scope in conjunction with a fundus contact lens. In order to establish compatibility with the diode delivery system, three lenses were used in this study. These were the Goldmann three mirror; the Mainster lens; or the Rodenstock panfundoscope lens. Laser spot size was constant at 300 microns, but as with all lasers the absolute spot size at the retina varied slightly with each lens. The power levels used for treatment varied with the clinical condition and with fundus pigmentation but routinely fell between 450 and 650 mW. Exposure durations were either 0.25 or 0.50 seconds.

The wavelength of emission and dielectric coatings on the optics within the laser delivery head of each instrument obviated the need for a mechanical safety shutter mechanism during exposures, this allowed an unimpeded retinal view throughout all treatment sessions. The power source in each laser was from a standard single phase 13 amp mains supply. Ancillary cooling facilities were not necessary for either instrument since collateral heat production was extremely low. When not in use, either instrument could be easily stored in a carrying case measuring 46cm × 33cm × 15cm and was light enough to be easily transportable.

Clinical Methods
All clinical work was carried out in either the Department of Ophthalmology at St Thomas' Hospital or the Retinal Diagnostic Department at Moorfields Eye Hospital.

Patients with a number of retinal vascular conditions for which laser photocoagulation is an accepted mode of therapy were treated in this study. These conditions were, proliferative diabetic retinopathy; exudative diabetic maculopathy; and retinal vein occlusion complicated by neovascularisation at the retina, the optic disc or established or threatened in the iris.

The aim of treatment of proliferative retinopathy in either diabetes or vein occlusions was closure or regression of any areas of neovascularisation. In those patients with established rubeosis iridis secondary to central retinal vein occlusion, photocoagulation attempted to cause regression of the rubeosis and forestall the onset of rubeotic glaucoma.

The aims of photocoagulation for exudative diabetic maculopathy were closure of intraretinal microvascular abnormalities and the resolution of macular hard exudates.

Therapy was carried out on a separate day from that of the pretreatment assessment and if possible all treatment was completed at one sitting. The pattern of laser treatment administered varied according to the condition.

Eyes with diabetic retinopathy and papillary neovascularisation had panretinal therapy[24] while peripheral new vessels were given either sector or panretinal photocoagulation depending on the extent of the lesions and area of ischaemia[25]. Exudative maculopathy had focal treatment to regions of microvascular abnormalities[26]. In those eyes with branch retinal vein occlusion, sector ablation was administered to the area of ischaemic retina indicated by fluorescein angiography[27]. Central retinal vein occlusions were treated with panretinal photocoagulation, with typically 500 burns applied to each quadrant[28]. In all conditions the immediate aim of photocoagulation was to produce a mild blanching of the retina with each burn.

During treatment careful note was made of any subjective sensations remarked on by the patient and the operator recorded his own observations. Patient review was at two weeks, six weeks and 12 weeks following treatment and at three monthly intervals thereafter.

Results
Over a period of six months, diode laser photocoagulation was performed on a total of 33 eyes in 30 patients. Detailed analysis of the results by each disease category will be the subject of subsequent reports when larger patient populations became available. However, in this account initial statistics will be presented for each group following a general consideration of the ergonomic aspects of diode laser treatment.

Use of Instrumentation
The hand-held, direct ophthalmoscope version was used for the first six patients treated (all with retinal vein occlusions) while the slit lamp model was employed for all subsequent cases. Both forms could be quickly and easily

set up for use in the clinic and no difference was found in the type of lesions produced with either instrument.

The greater magnification and smaller field of view made treatment with the hand-held device a lengthier procedure, and poor target fixation made macular photocoagulation difficult. In contrast the slit lamp instrument allowed more accurate aiming, the patient being stabilised through the contact lens and the head rest of the microscope. The greater field of view and the better retinal illumination were also perceived advantages by the operator. Patient comments indicated a strong preference for the direct ophthalmoscope modality mainly because no contact lens was required and that they could assume a more relaxed posture.

In each instrument the red aiming beams were usually clearly visible, but where there was extravascular blood in either the vitreous or the retina, the retinal image of the aiming beam tended to fade in sharpness and brightness. The absence of an occluding safety shutter allowed an uninterrupted retinal view during photocoagulation, and therefore it was possible to visualise the full process of development of a retinal burn. This uninterrupted view also speeded treatment as the operator never lost orientation or location during procedures as sometimes occurs in response to eye movements during shutter closure using conventional systems.

An additional feature of the shutterless system was that retinal treatment was a much quieter procedure than with conventional lasers, the only sound being that of the faint click of the foot switch during each exposure. As only the aiming beam was visible there were no bright flashes during photocoagulation, although at higher power levels a faint transient orange fluorescence of the retinal pigment epithelium was visible. Several patients who had been treated previously with an argon laser stated that these features made diode laser photocoagulation a less stressful experience.

Reliability of the instruments was high. The slit lamp version has performed over 100,000 exposures, to date, without malfunction.

The Laser Burns

In a sequence of initial exposures the power level was set to produce a grey-white chorioretinal lesion, corresponding to a mild burn (typically 450–650 mW). The immediate post exposure appearance of the lesion was similar to that seen in relation to krypton laser irradiation: that is a slightly less distinct burn than that typical of argon irradiation.

The degree of retinal pigmentation influenced the power level at which a clinical threshold lesion could be obtained. Generally, highly pigmented fundi required lower power settings for photocoagulation (450–550mW) than lightly pigmented fundi (500–750mW). All lesions were made with a constant exposure duration of 0.25 seconds. Within one week of treatment the burns had become pigmented scars essentially identical to those produced by other forms of laser irradiation. No complications were seen such as choroidal haemorrhages, or tears in the retinal pigment epithelium. The presence of media opacities required an increase in power to produce a burn, but it is noteworthy that the laser radiation at 810nm was observed to be able to penetrate a thin film of preretinal haemorrhage (approximately 150 microns in thickness) in sufficient concentration that a burn ensued at the retinal pigment epithelium.

Clinical Results
(A) Proliferative Diabetic Retinopathy

Sixteen eyes were treated in 14 patients who had either optic disc or retinal neovascularisation. Ten patients were male and four female. The mean age was 52 years (range 26–69) and the mean period of follow-up was four months (range three months to six months). During panretinal photocoagulation, the number of burns that were applied typically ranged from 2,500 to 3,500.

Partial or total closure of the new vessels was observed in 13 of 16 (81%) eyes within eight weeks of treatment. During the period of follow-up, the visual acuity on a standard Snellen chart was maintained to within one line of the pretreatment level in 15 out of 16 eyes. In the other eye, vitreous haemorrhage from disc new vessels occurred three months following treatment, which reduced the visual

acuity from 6/9 to counting fingers. The haemorrhage resolved with visual recovery to its former level within one month. Further photocoagulation was performed and the patient is currently under review. In none of the patients were treatment-related anterior segment complications observed, such as corneal or lenticular changes.

Four patients, in common with several from the other groups occasionally reported symptoms of discomfort during treatment. Comments were encountered most often at higher power levels, or where photocoagulation was applied to areas of lightly pigmented retina. In no instance was it found necessary to discontinue therapy due to unacceptable levels of discomfort, but in one case retrobulbar anaesthesia was administered when further treatment was carried out. This patient had previously required argon laser therapy to the other eye, also under retrobulbar anaesthesia. Other patients who had undergone argon therapy to the fellow eye favoured diode treatment. In particular, patients commented upon the absence of both noise and the intense and repetitive flashes of light.

Case Report 1
A 67 year old insulin dependent diabetic male presented with optic disc and retinal neovascularisation in the left eye (Figure 3). Diode laser panretinal photocoagulation was performed, a total of 3,677 burns being applied with an exposure duration of 0.25 seconds, a laser spot size of 300 microns and power of 550–700 mW. No problems were encountered during treatment apart from the patient experiencing mild discomfort at higher power levels of exposure.

On review at two weeks the laser lesions showed the typical appearance of pigmented scarring and the disc new vessels showed signs of regression (Fig 4). At six weeks fluorescein angiography showed an absence of leakage from the previously patent new vessels (Fig 5). Subsequent examination has shown no recurrence of the treated lesions.

(B) Exudative Diabetic Maculopathy
Five eyes in four patients were treated in this group, three males and one female with a mean age of 65 (range 63–66). The mean period of review was 18 weeks (range 14 weeks to eight months).

Focal photocoagulation was administered to microvascular abnormalities (MVA) within the areas of hard exudate. The MVA were principally microaneurysms but in one case was a macroaneurysm. No immediate alteration in the appearance of the treated vascular lesions was seen, the infrared laser energy being transmitted through the vascular lesions and being absorbed by the underlying retinal pigment epithelium and choroid.

Within eight weeks there was a reduction in the observed number of vascular lesions in the treated areas of each eye and there was evidence of the hard exudates beginning to resorb. The period of follow up in this group is
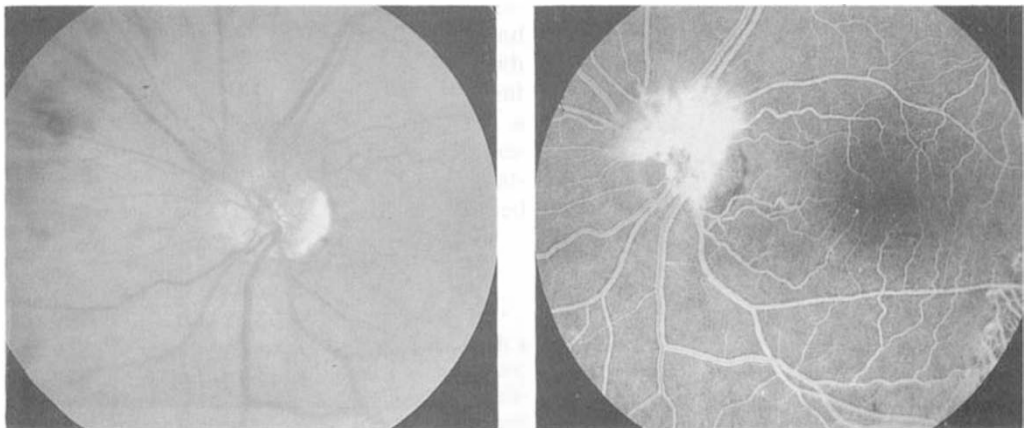

Fig. 3 *Case 1. Left: Fundus photograph showing papillary neovascularisation in the left eye of an insulin-dependent diabetic. Right: Pre-treatment fluorescein angiogram of same eye demonstrating leakage from the disc new vessels.*
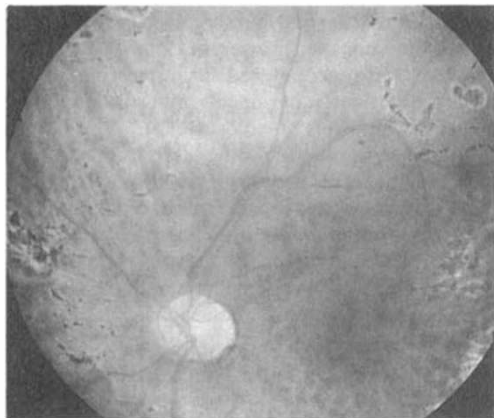
Fig. 4. *Case 1. Two weeks following panretinal photocoagulation, the laser burns demonstrate a typical appearance of pigmented scarring.*
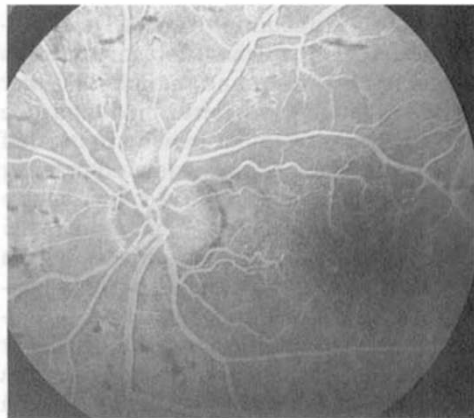

Fig. 5. *Case 1. Six weeks following treatment, fluorescein angiography shows an absence of leakage at the optic disc, confirming regression of the new vessels.*

too short to allow any firm conclusions to be drawn, but the resolution of the lesions appear to be continuing and in four cases the Snellen visual acuity has improved by one or two lines. No side effects were noted in any case.

Case Report 2
A 65 year old non insulin dependent diabetic presented with a circinate area of hard exudates supero-temporal to the right macula. Central to the ring of exudate was a retinal macroaneurysm (Fig 6). Visual acuity was 6/9. 21 burns were applied to

the region of the macroaneurysm. Power was 500 mW, spot size was 200 microns and the exposure duration was 0.5 seconds. No adverse symptoms were reported by the patient. Eight weeks later there was visible laser scarring deep to the MVA, which was still visible and some signs of resolution of the exudates. Twenty weeks following treatment, the central lesion had disappeared and the area of exudate had resorbed considerably (Fig 7). His visual acuity remained unchanged, but there was evidence of pre-existing macular degenerative changes.

(C) Retinal Vein Occlusion
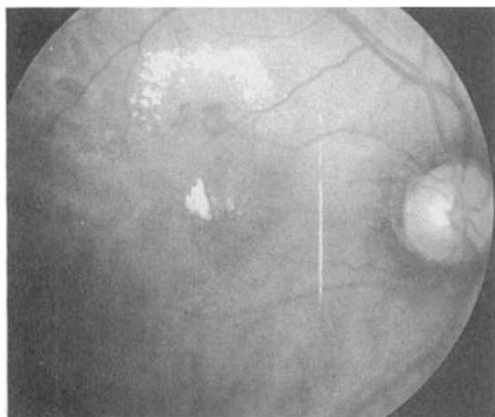Twelve patients were treated for either

Fig. 6. *Case 2. Fundus photograph of a patient with non-insulin dependent diabetes, which shows a right exudative circinate maculopathy surrounding an haemorrhagic microvascular abnormality.*
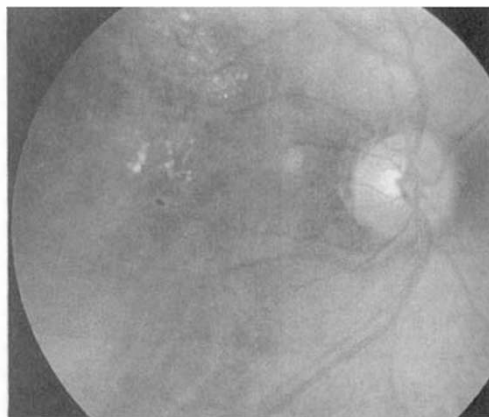

Fig. 7. *Case 2. Four months following focal photocoagulation the central lesions have resolved and there is considerable resorption of surrounding exudates.*
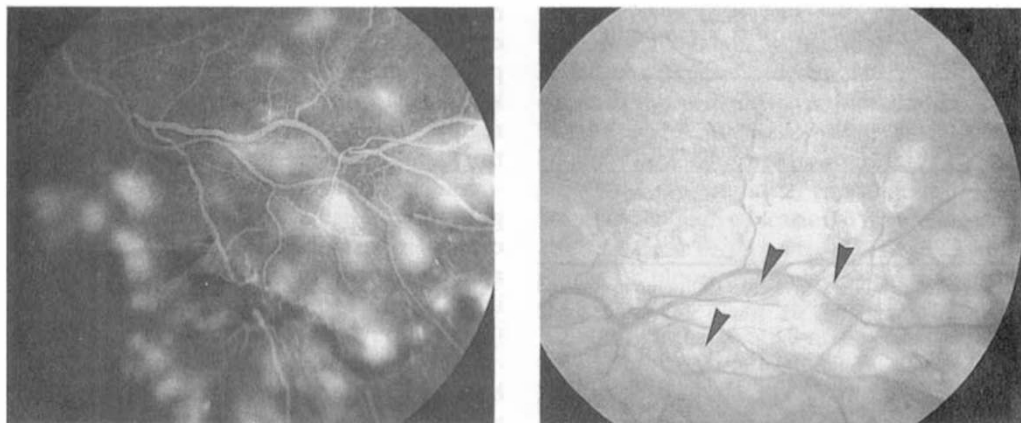
Fig. 8. *Case 3. Left: Pre-treatment fluorescein angiogram of a left inferotemporal branch retinal vein occlusion with retinal neovascularisation, which demonstrates several areas of leakage from the neovascular complexes. Right: Fundus photograph in the same patient, immediately following laser sector ablation. Areas of neovascularisation are indicated by arrows.*

branch retinal vein occlusion and optic disc or retinal neovascularisation (eight eyes); or central retinal vein occlusion with either established or threatened rubeosis iridis and in one case also with optic disc new vessels (four eyes). Eleven patients were female and one was a male. The mean age was 67 years (range 53–81) and the mean follow up period was six months (range four months to ten months).

Six out of eight (75%) patients with papillary or retinal new vessels secondary to branch vein occlusion had closure of the vessels within eight weeks of treatment. Two out of four patients with central retinal vein thrombosis had partial regression of the vessels and in one there was complete regression of both the iris and optic disc new vessels. One patient with severe retinal ischaemia following a central retinal vein occlusion has not developed rubeosis three months following treatment. None of the patients has developed rubeotic glaucoma.

Case Report 3
An 81 year old hypertensive lady presented with a left infero-temporal branch retinal vein occlusion. There were several tufts of forward retinal neovascularisation surrounded by areas of intra-gel haemorrhage (Fig 8).

Two-hundred and thirty-five burns were applied to the area of ischaemic retina. Power was 500–650 mW, spot size 200 microns and exposure duration 0.5 seconds. Apart from a slight 'pricking' sensation the patient reported no adverse symptoms and no other side effects were observed. Eight weeks later, the new vessels had regressed, closure being confirmed on angiography (Fig 9). No recurrence of the vessels has been observed subsequently.

Discussion
In the present paper, the maximum follow up time was nine months and clearly this is too short a period from which to draw firm con-
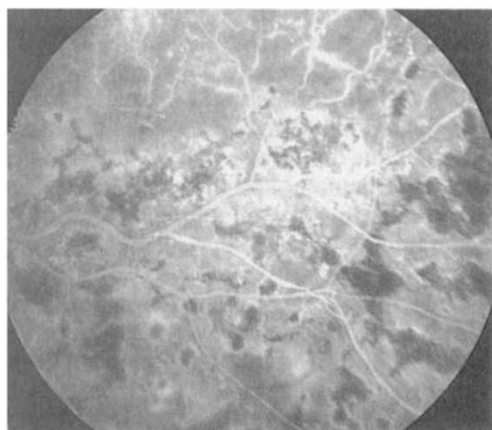

Fig. 9. *Case 3. Following laser therapy, closure of the retinal new vessels is confirmed by fluorescein angiography.*

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Table I *Diabetic neovascular regression induced by diode laser in comparison with argon and krypton photocoagulation*

Laser modality ('n' refers to number of eyes in each group)	Complete or partial regression of disc or retinal new vessels*
Diode (n = 16)	13 (81%)
Argon† (n = 64)	52 (81%)
Krypton† (n = 59)	53 (91.5%)

* Observations made four weeks following argon and krypton therapy and six weeks following diode photocoagulation.
† From: Blankenship GW: Red krypton and blue-green argon panretinal photocoagulation for proliferative diabetic retinopathy: a laboratory and clinical comparison. *Trans Am Ophthalmol Soc* 1986, **84**: 967–1003.

clusions concerning the therapeutic efficacy of the diode laser in relation to retinal vascular diseases in general.

The beneficial effects of photocoagulation in treating the complication of branch retinal vein occlusion have been firmly established[29] and have also been demonstrated in relation to red laser light from krypton lasers [30]. The studies have all demonstrated that regression usually begins within a few weeks following laser treatment and that there is a low incidence of recurrence. Given the temporal basis of this therapeutic effect and that our average follow up time was seven months we can draw significant conclusions from our eight patients suffering from this condition. The diode laser emission was in the infrared and the clinical effects appear exactly comparable to those previously observed with the krypton laser.

Although the number of patients who had been treated for central vein retinal occlusion was small, the observed resolution of rubeosis following treatment and the absence of onset of thrombotic glaucoma in any eye were encouraging results.

In contrast, early analysis of results obtained from the treatment of eyes with proliferative diabetic retinopathy is more difficult. The underlying metabolic abnormality is complex and may continue to exert an effect on the retina despite apparently successful laser photocoagulation. A longer period of review of this group is therefore necessary in order to allow firm conclusions to be drawn

regarding the efficacy of diode laser photocoagulation for this condition. Historical comparison with previous trials using argon and krypton lasers demonstrate similar rates of regression at comparable periods following treatment (Table I).

In the assessment of each of the three groups of patients there was little observed change in visual acuity following treatment and this is comparable to visual results following treatment with other wavelengths (Table II).

Currently, the preferred technique for the laser treatment of diabetic exudative maculopathy is to irradiate focally microaneurysms with argon laser radiation. The underlying concept in such treatment is that closure of these discrete sources of leakage result in eventual resorption of exudates. There are few clinical studies of krypton radiation for such treatment because of the poor absorption of red laser light in retinal blood vessels.

In the present study the use of an infrared system correlated with a protocol demanding focal irradiation of microaneurysms may seem illogical as even less radiation at 810 nm will be absorbed within microaneurysms than at krypton 647nm. In argon laser irradiation if the microaneurysm is large then significant amounts of energy will be focally deposited within the abnormal vessel and the resulting thermal gradients may produce an acute thrombosis. Clinically, this is frequently observed as the vascular lesion changes in

Table I *Visual acuity following photocoagulation for diabetic neovascularisation*

Laser modality ('n' refers to number of eyes in each group)	Post treatment Snellen acuity within one line of pre-treatment value*
Diode (n = 16)	15 (93%)
Argon† (n = 21)	13 (62%)
Krypton† (n = 23)	15 (66%)

* Observations made four weeks following argon and krypton therapy and six weeks following diode photocoagulation.
† From: Blankenship GW: Red krypton and blue-green argon panretinal photocoagulation for proliferative diabetic retinopathy: a laboratory and clinical comparison. *Trans Am Ophthalmol Soc* 1986, **84**: 967–1003.

colour from red to greyish white. In diode treatment the transparency of the vascular lesion to this wavelength precluded the generation of significant thermal disturbance in the aneurysm and therefore acute spasms or thrombosis were not observed. However, at review, several weeks post treatment microanurysms within the areas of focal treatment had resolved together with resorption of exudates. Recent laboratory studies employing tissue culture techniques on both human retinal pigment epithelial cells and retinal capillary endothelial cells are beginning to demonstrate possible biochemical mediators which induce beneficial tissue responses secondary to photocoagulation[31,32]. Such factors may be relatively acute such as relating to opening of the blood retinal barrier or death of pigment epithelial cells[33], or may be somewhat delayed and depend upon a body of pigment epithelial cells proliferating[34]. In the former case, newly proliferated capillary endothelial cells may result in retinal vessels with a lower permeability and therefore less leakage of plasma constituents, while in the latter the newly formed retinal pigment epithelial cells may increase the removal of fluid from the retina. Proliferating retinal pigment epithelial cells have also been shown to be correlated with the presence of factors in the vitreous which are seen to inhibit retinal vascular endothelial cell division *in vitro* and may play a role in the effect of panretinal ablation[34]. From our observations and these laboratory studies it seems that much of the beneficial effect of photocoagulation in retinal vascular disease derives from processes dependent upon energy deposition in the retinal pigment epithelium rather than in retinal vessels themselves. If this is the case then the match of emission wavelength of clinical lasers in relation to the haemoglobin absorption spectra is relatively unimportant.

The possibility of using longer wavelengths of photocoagulation has several advantages. First, the transmission of the human cornea and lens is significantly higher in the red and infrared region of the spectrum than in the blue[35]. Transmission in these former spectral regions is not very age dependent in that the progressive accumulation of pigment in the lens nucleus which may result in yellowing of the lens is associated with only 7% transmission loss at 800nm whilst that at 488nm is 20%[36]. As most photocoagulation therapy is conducted in the elderly and as transmission losses are common in diseased eyes, the use of longer wavelength light significantly reduced problems of attenuation of radiation by pretarget absorption or scatter. This advantage is also apparent in those cases where haemorrhages or blood products are present in the vitreous.

Although the relative absorption of radiation at 800nm in the retinal pigment epithelium is only about 40% of that of argon at 488nm[37], it is obviously sufficient to produce a clinical burn and induce the observed therapeutic effects.

A further advantage of using infrared radiation as a means of coagulation is the reduced risk of possible photochemical damage to the patient's retina due to intraocular scatter, the so-called "blue light hazard".[38] This also has implications for the ophthalmic laser surgeon as recent studies have shown that they also experience a "blue light hazard" and a resultant colour vision defect from exposure to reflections of the aiming beam during argon laser therapy[39].

In this first report of the use of diode lasers in the treatment of retinal conditions, in addition to specific information being gained on its therapeutic efficacy, valuable data have been collected on the ergonomic aspects of these systems when in routine clinical use.

The pilot study was constructed to investigate the therapeutic potential of the diode laser and also to allow a measure of comparison with conventional lasers particularly regarding ease of utilisation and patient tolerance.

Both versions of the laser were reliable, no malfunction being encountered during the period of study. Their portability and simplicity of use conferred a flexibility of operation not allowed with current laser systems, which are restricted by reason of their size, power requirements and cooling facilities. These factors, together with the projected lower capital and maintenance costs of diode lasers will allow their use outside the major ophthalmic centres and also enable use in those third world countries which have, at

present, only a few ophthalmic lasers to serve whole populations.

The absence of the need for a safety shutter is a novel feature of the diode laser. In current laser apparatus it is not possible to view the formation of retinal lesions during exposure. Recent reports of failure of the shutter during argon laser therapy resulting, in at least one instance, in retinal damage to the surgeon, highlight the disadvantages of the necessity for a safety system that relies on moving parts, with the potential for malfunction[40].

The hand-held version proved effective in producing retinal burns and in treating retinal vein occlusions, although comparatively few patients were treated. The relative disadvantages of limited field of view, reduced illumination and unsuitability for macular photocoagulation tends to mitigate against it gaining widespread acceptance and are similar to many of the criticisms of the ergonomics of the early ruby laser ophthalmoscopes. There are however certain situations where it could be of advantage. Patients who, for reasons of physical disability, cannot sit at a slit lamp microscope could be treated while lying on an examination couch. Those patients who would need a general anaesthetic due to exceptional intolerance of laser treatment, or for reasons of extreme youth might also be suitable for this type of therapy.

The advantages conferred by the slit lamp model in terms of retinal imaging and illumination and ease of targeting allow a greater versatility of use in a variety of conditions, including macular photocoagulation, and in the presence of significant media opacities.

The visibility of the red aiming beam was satisfactory apart from in the presence of intragel haemorrhage, when the retinal view itself tended to be compromised.

In conclusion, we have found that an experimental diode laser system mounted on a conventional Haag Streit slit lamp was extremely easy to use and was very reliable. To date, the clinical results are compatible with those obtained from the use of conventional laser systems. The efficacy and potential price of diode laser photocoagulation should have profound implications for ophthalmic practice in the next decade.

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