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Aiming Criteria for Neodymium-YAG Laser Trabeculotomy

A Clinico-Pathological Study

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Summary

Recently reported clinical and experimental studies have shown that pulsed neodymium-YAG laser trabeculotomy may reduce intraocular pressure but not in all cases. We report a clinico-pathological study designed to delineate the aiming criteria required to produce a fistula between the anterior chamber and the canal of Schlemm. In summary, the aiming beam must be centred on the reflecting surface of the gonioscopic contact lens, and aimed at the posterior trabecular meshwork. This study also indicates that the energy levels required to produce a discrete trabeculotomy *in vivo* are similar to those determined by *in vitro* studies.

The aim of treatment of primary open angle glaucoma is the reduction of intraocular pressure. Recent research has indicated that this purpose may be achieved using a pulsed laser to create fistulae between the anterior chamber and the canal of Schlemm.[1-5] It has been estimated that 20 perforations each 10 μm in diameter should restore normal outflow facility in open-angle glaucoma.[6] For such fistulae to remain patent without being occluded by scar tissue they should, in theory, pass directly into the canal of Schlemm without penetrating the underlying sclera.[7]

Preliminary *in vitro* studies have indicated that the operating parameters of the laser apparatus must be precise to achieve this aim.[7-9] However, the aiming criteria required for correct placement of the laser lesions *in vivo* have not, hitherto, been described.

We describe our initial experimental results in which we have established the correct positioning of the contact lens and the optimum location of the aiming beam required to produce fistulae between the anterior chamber and the canal of Schlemm, in man.

Patients, Material and Methods

Three patients with untreatable choroidal melanoma at the posterior pole of the eye volunteered for the study. The guidelines laid down by the Hospital Ethical Committee were observed. The laser system used was the Hyper-YAG2000 produced by J. K. Lasers Ltd as described previously.[7] This was linked by means of an articulated arm to a delivery unit attached to a Zeiss slit-lamp. The convergence angle for this system is 14°.

Each patient was seated at the slit-lamp and the trabecular meshwork viewed through a prismatic gonioscopic contact lens held on the eye. Between 3 and 5 laser applications were applied to the trabecular meshwork between the meridians unaffected by tumour at the posterior pole. Two eyes were enucleated at 18 hours following laser treatment and the third at half an hour. They were fixed by immersion in 3 per cent cacodylated buff-

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ered glutaraldehyde. For each eye the calotte containing the laser lesions but not tumour was removed, and the diametrically opposite calotte was removed as a control. Wedges containing the trabecular meshwork and adjacent tissues were prepared from each calotte and submitted to critical point drying and gold coating for scanning electron microscopy (Jeol JSM T200). The specimens showing laser lesions were photographed and reprocessed for light microscopy according to the method described previously[8].

Serial 1 μm sections were taken at 10 μm intervals through one selected lesion from each patient. Each light microscopic section was photographed and the central section passing through each lesion determined by inspection of the serial photographs. The dimensions of a lesion from each of the second and third specimens were determined both from the SEM pictures (after appropriate calibration) and from the light microscopic sections.

Results

Table I summarises the results obtained. The clinical details and the morphological appearances of the lesions produced are described for each patient.

Patient 1

The laser was aimed at the centre of the inferior trabecular meshwork, however, no clinically detectable lesions were obtained at 30 mJ. (The energy level required by the laser to produce a fistula into the canal of Schlemm *in vitro*.) The energy delivered was increased to 48 mJ when clinical evidence of plasma formation (bubbles in the anterior chamber) became apparent. For the final application (Fig. 2a) care was taken not to have the aiming beam off centre with respect to the gonioscopic mirror (Fig. 1). The shock wave felt by the patient and clinician (GND) was more marked with this final application.

Figure 2a shows the most extensive of the three lesions produced at this energy level, all of which were similar. The section (Fig. 2b) passing through this lesion at the approximate position indicated in Figure 2a, shows that there is only superficial trabecular disruption.

Patient 2

The laser was applied to the inferior trabecular meshwork taking care, on this occasion, to centre the aiming beam on the gonioscopic mirror. Treatment was applied between the middle and anterior portion of the trabecular meshwork increasing the energy level to 37 mJ when plasma formation was observed. At this level 3 out of 6 pulses produced clinically apparent lesions in the trabecular meshwork.

Two lesions were seen on scanning electron microscopy (SEM) (Fig. 3a), the third was not included in the calotte. The maximum innermost diameter of the hole indicated in Figure 3 was 125 ± 10 μm as measured both from the SEM and from the sections.

Figure 3b is a section taken in the plane indicated by the arrow on Figure 3a.

It is clear that there is no communication with Schlemm's canal.

Patient 3

The energy of the Nd-YAG laser was set at 30 mJ and the laser was centred upon the gonioscopic mirror. Ten shots were applied to the posterior trabecular meshwork of which 3 produced plasma and gave rise to clinical evidence of damage to the trabecular meshwork. Two of these lesions were associated with reflux of blood from the canal of Schlemm into the anterior chamber (Fig. 4a). The eye was removed within half an hour of treatment and the blood clots are clearly visible in relation to each lesion. The section taken at the position indicated by the arrow (Fig. 4b) shows clearly that there is a patent fistula into the anterior part of Schlemm's canal. The minimum diameter of the lesion as it entered the canal of Schlemm measured from the serial sections was 140 ± 10 μm.

Table I *Clinical data concerning the pulsed Nd-YAG laser treatment received by each patient*

Patient	*Energy*	*Time of laser before enucleation*	*Calotte*	*No of shots with plasma*	*No of shots with blood reflux into anterior chamber*	*Intraocular pressure (mm/Hg)*		
						Pre-op	*1 hr*	*24 hrs*
1	Increase to 48 mJ*	17 hours	Inferior	3 out of 8	0	16	15	16
2	37 mJ	18 hours	Inferior	3 out of 6	0	16	14	16
3	30 mJ	30 minutes	Superior	3 out of 10	2	14	—	—

* See text.

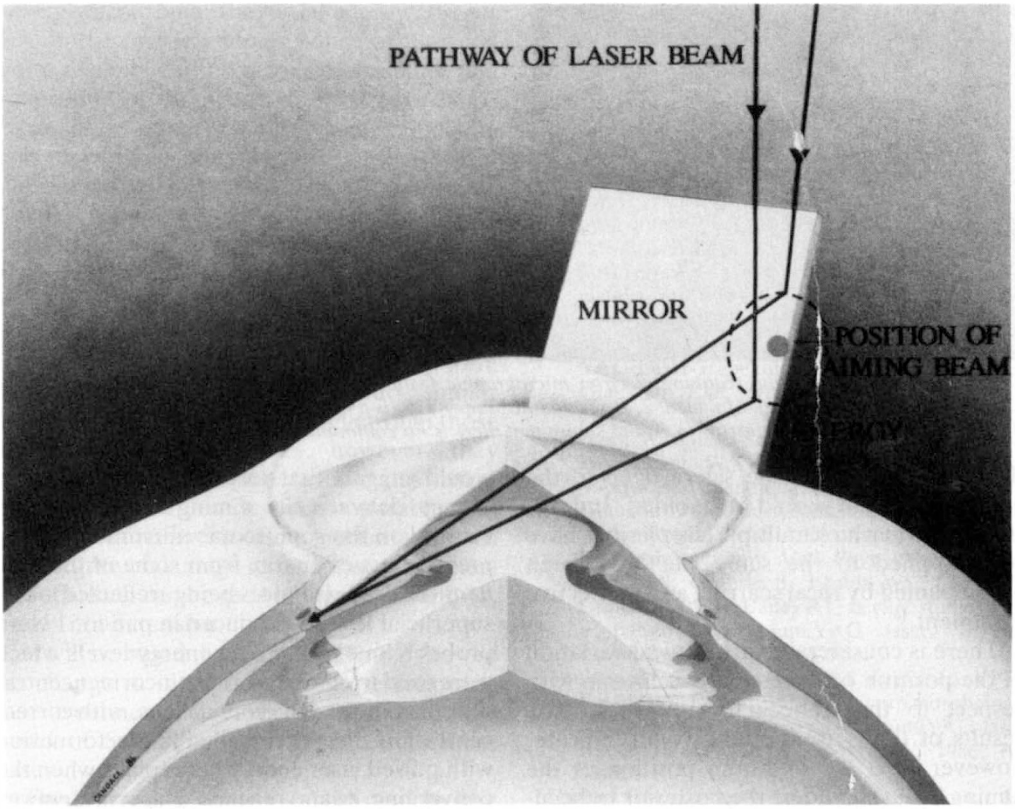

Fig. 1. *Diagram illustrating why the helium neon aiming beam must be centred on the gonioscopic mirror in order to prevent loss of energy due to reflection of only part of the converging Nd-YAG laser beam.*

Discussion

A number of studies have provided evidence that glaucoma can be successfully treated by pulsed laser trabeculotomy.[1-5] However, the energy levels chosen, the number of lesions applied and the position of the aiming beam (the middle of the trabecular meshwork in most studies) have been chosen empirically. It has been argued that for a YAG-laser trabeculotomy to remain patent, scarring engen-

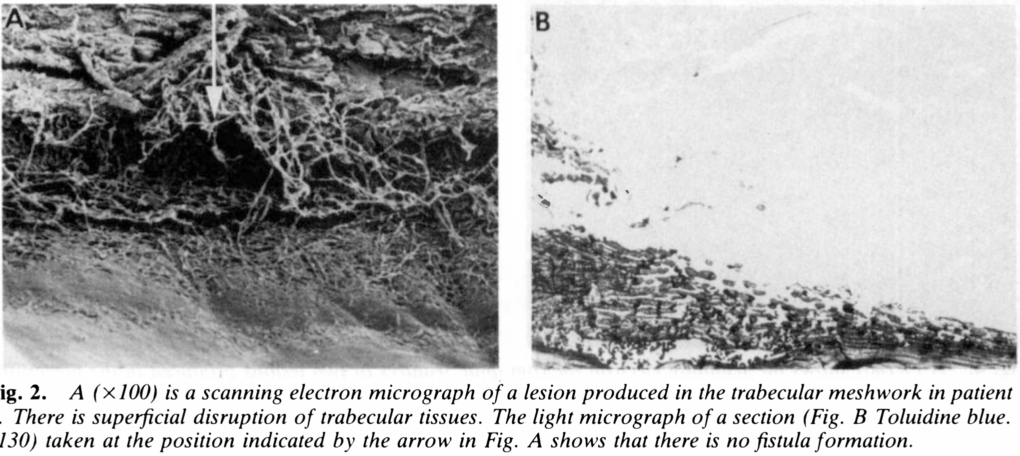

Fig. 2. *A (×100) is a scanning electron micrograph of a lesion produced in the trabecular meshwork in patient 1. There is superficial disruption of trabecular tissues. The light micrograph of a section (Fig. B Toluidine blue. x130) taken at the position indicated by the arrow in Fig. A shows that there is no fistula formation.*

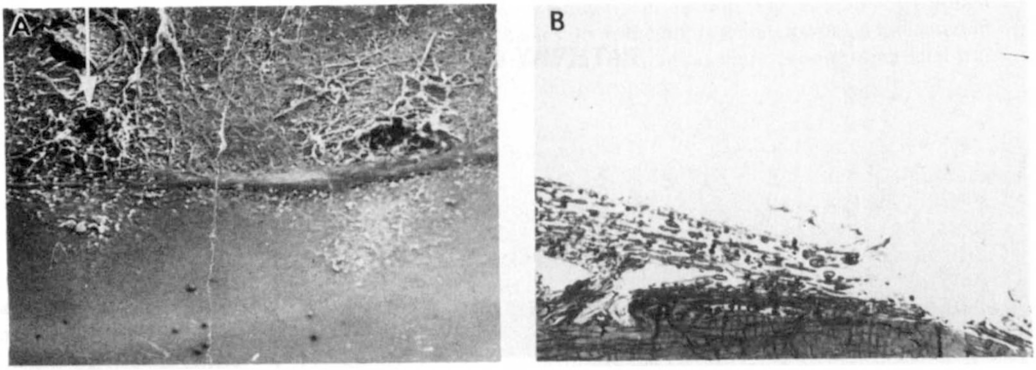

Fig. 3. *A (×70) shows the scanning electron micrographic features of two of the lesions produced in the anterior trabecular meshwork of patient 2. B (Toluidine blue. ×130) is a light micrograph of the section taken at the position indicated by the arrow in A and shows that there is no communication with the canal of Schlemm.*

dered by damage to the sclera deep to the canal of Shlemm should be avoided. Indeed, the studies in which multiple laser lesions have been applied to the same site have been accompanied by focal scarring and ineffective treatment.[10]

There is considerable anatomical variation in the position of the canal of Schlemm with respect to the trabecular meshwork. The results of the present study would indicate, however, that the optimum position of the aiming beam should be the posterior trabecular meshwork, just anterior to the scleral spur. Reflux of blood into the anterior chamber provides clinical evidence of fistula formation.

It has also been shown, *in vitro* at least, that the energy levels required to produce a fistula into the canal of Schlemm without perforating the underlying sclera are precise. Our study would suggest that to produce reproducible energy delivery the aiming beam must be centred on the gonioscopic mirror in order to prevent loss of energy from some of the incident laser pulse not being reflected. The superficial lesions produced in patient 1 were probably due to the high energy levels which were used to compensate for incorrect centration. Rotation of the contact lens, with correct centration then occurred. Plasma formation with pulsed laser energy takes place when the converging beam reaches a specific energy density. At high energy levels plasma formation and tissue disruption occurs proximal to the focal plane.

Plasma formation was not observed clinically for every laser application, a phenomenon observed in previous *in vitro* experiments. While the plasma, once formed, is

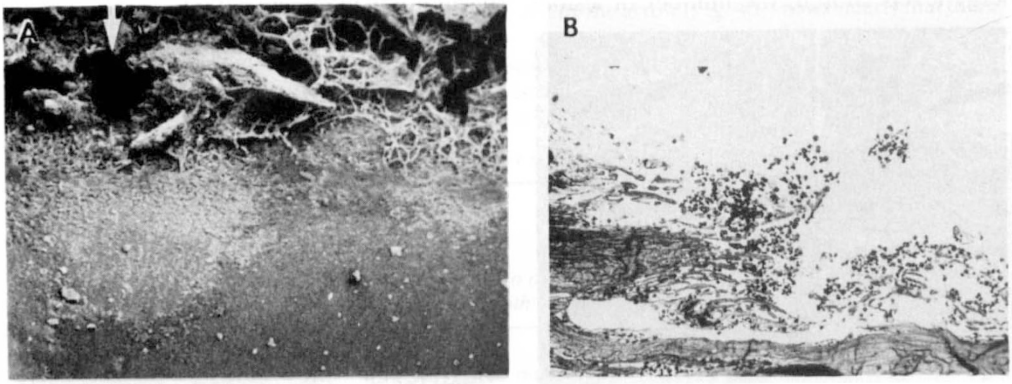

Fig. 4. *A (×100) shows the scanning electron micrographic features of two lesions produced in the posterior trabecular meshwork of patient 3. Fig. B (Toluidine blue. ×130) is a light micrograph of the section taken at the position indicated by the arrow in A and shows that there is a communication into the anterior portion of the canal of Schlemm.*

strongly absorbing, the initial energy absorption in the first few nanoseconds of the laser pulse depends on the details of structure and absorption of the material at the laser beam focus. If insufficient energy is absorbed no plasma will be formed because of the threshold nature of the plasma formation process. Small scale and otherwise insignificant variations in tissue properties may then lead, in an apparently unpredictable manner, to some pulses of a given energy producing plasma while others do not.

The energy levels used in this study were close to those required to produce similar lesions *in vitro.*[7,8] These are higher than those reported in other studies, however, they solely reflect the characteristics of the instrument and the values are not comparable with results obtained with other instrumentation. The degree of damage to the adjacent corneal endothelium can be seen in Figures 3a and 4a, and is not extensive.

It will be noted that patients 1 and 2 showed no change in intraocular pressure following laser treatment. However, no fistulae into the canal of Schlemm were produced in these cases.

The operating criteria established by the experimental investigations described are now being applied to patients with primary open angle glaucoma, with initially encouraging results.

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