Neodymium-YAG transscleral cyclocoagulation in rabbit eyes

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SUMMARY Transscleral ruby cyclocoagulation has been successfully used to lower intraocular pressure. The recent commercial availability of Nd-YAG lasers with a thermal mode provides a possible alternative by which to perform this procedure. We treated one eye of seven pigmented rabbits using the thermal mode of the Nd-YAG laser. The intraocular pressures were followed up for three months. The treated eyes had significantly lower mean intraocular pressures than the untreated contralateral eyes ($p < 0.001$). Moreover, the decrease was sustained over the three-month duration of the study. Pathological examination revealed very selective destruction of the ciliary processes, with sparing of the overlying ciliary muscle, sclera, and conjunctiva. The potential value of this mode of therapy for use in patients with glaucoma is discussed.

Transscleral ruby laser cyclocoagulation was first used by Beckman and colleagues^{1,2} to lower intraocular pressure (IOP). Owing to the lack of general availability of such lasers this technique has not been much used clinically over the years.

Neodymium-yttrium-aluminium-garnet (Nd-YAG) lasers have recently become commercially available. These lasers provide a possible alternative by which transscleral ablation of the ciliary processes can be performed.

Nd-YAG lasers (along with ruby lasers) are pulsed lasers. They emit light in the infrared region of the spectrum (wavelength 1064 nm). The duration of the emitted pulse is in the millisecond range ('free-running' or 'thermal mode'). If a Q-switch or mode-lock shutter is used, the pulse duration is reduced into the nanosecond or picosecond range respectively, with power levels of several hundred thousand watts. With such enormous power levels electrons, rather than being absorbed, are stripped off molecules and atoms, causing plasma formation (a mixture of ions and free electrons).³

In contrast, when used in the thermal mode, the infrared pulses are prolonged, and therefore the laser has a much lower power output (100-200 W). Since the infrared wavelengths are in the invisible portion

of the spectrum, the absorption properties are very different from those of conventional argon or krypton lasers. The infrared energy has been shown to penetrate six times more deeply into tissues than that of the argon laser before being absorbed.⁴ The infrared energy can thus penetrate the scleral wall before producing a thermal reaction in the region of the ciliary processes.

The purpose of this study was, firstly, to investigate whether transscleral treatment with the thermal mode of the Nd-YAG laser can decrease the intraocular pressure (IOP) in pigmented rabbits over a three-month period, and secondly to study the sclera and ciliary processes histologically to determine the effects of this form of treatment.

Methods and materials

Seven pigmented rabbits weighing 2-3 kg were used in the study. The animals were anaesthetised with sodium pentobarbital injected intravenously into an ear vein. One eye of each animal was randomly selected to be treated with the laser. The untreated eye served as the control.

Each treated eye received 24 burns by the thermal mode of the Lasag MR 2 Nd-YAG laser (Fig. 1). The laser burns were placed 1 mm posterior to the limbus, with a pulse duration of 20 ms, at a pulse energy of 2 joules (resultant power 100 W). The aiming beam

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Fig. 1 Location and number of Nd-YAG laser burns in relation to the limbus.

was focused on the conjunctiva, but the laser was offset 2.4 mm (offset 6 on the Lasag) in order to treat the ciliary processes selectively.

One animal died immediately after laser treatment as a complication of general anaesthesia. The treated eye was submitted for pathological examination.

The remaining six animals had daily IOP measurements for the first three weeks, and then weekly IOP measurements for a total of three months. Intraocular pressure measurements were performed in a masked fashion with a Perkins hand-held applanation tonometer.⁵ The pressure measurements were performed at 0700 daily, with the animals awake, with local anaesthesia by topical proparacaine hydrochloride 0.5% over a three-month period. One drop

of Maxitrol (dexamethasone 0.1%, polymyxin B, neomycin) was instilled into both eyes for the first three weeks of the study.

One of the animals had to be destroyed after four days because of a broken hind leg. The treated eye from this animal was also sent for pathological examination. At the end of three months the remaining five rabbits were killed and their eyes were examined histologically.

Results

Three of the six treated eyes developed hyphaemas, ranging from 20% to approximately 80%. All these hyphaemas disappeared without apparent consequence within two weeks. Moderate conjunctival injection was present in all treated eyes for the first week.

Analysis of variance was used to compare the treated and control eyes. Nd-YAG laser treatment was found to significantly lower the IOP in the treated eyes ($p < 0.001$). Furthermore the difference between the treated and control eyes over the three-month course of the study showed no statistically significant change ($p > 0.7$). In other words the IOP lowering effect of the laser treatment showed no tendency to diminish over the three-month period of observation. Fig. 2 charts the effect of the Nd-YAG laser cyclocoagulation on rabbit IOPs. Each point represents the mean of three readings.

All treated eyes showed areas of depigmentation of ciliary epithelium on gross examination, without any evidence of damage to the exterior scleral surface. Pigment dispersion was more diffuse in animals examined at three months in contrast to the localised burn depigmentation in the animal which

Fig. 2 Mean IOP values after Nd-YAG therapy.

Fig. 3 Histological examination of laser burns 24 hours after treatment, showing 'blistering' of pigmented ciliary epithelium with surrounding mild oedema. Haematoxylin and eosin.

died shortly after its laser treatment. Histological examination of this animal showed a 'blistering' effect on the pigmented ciliary epithelium, which was lifted off the stroma, showing oedema in the immediate area (Fig. 3). The ciliary muscle fibres appeared to be intact, as did sclera.

The animals examined at three months showed a variety of changes depending on the location of the burn. The usual change was dispersion of pigment and fibrosis, with some atrophy of ciliary muscle fibres in the immediate area of the burn (Fig. 4). The animals that bled had so much haemorrhagic necrosis that the laser burns were obscured.

Discussion

Beckman and colleagues¹² successfully used a

specially designed ruby laser for transscleral cyclocoagulation during the early 1970s. Wilensky *et al.*⁶ have recently shown that transscleral cyclocoagulation lowers IOP in pigmented rabbits, using the thermal mode of the Nd-YAG laser. Their results suggested that the higher energy levels (1.5–2.0 J) may be successful in producing a sustained lowering of the IOP. Our study confirms this effect. The treatment parameters and follow-up time used in our study, however, were different from those of Wilensky *et al.* We used a relatively high energy level (2 J) but with a 20 ms pulse duration rather than 10 ms. The resultant power was therefore 100 W rather than 200 W. Our animals were all followed up for a period of three months, against a maximum of 48 days follow-up in the other study. We also set the laser on 2.4 mm 'Offset' so as selectively to destroy

Fig. 4 Histological examination of laser burn three months after treatment, showing pigment dispersion and fibrosis in the ciliary processes. Haematoxylin and eosin.

the ciliary body and processes, unlike the other study. With these modes of treatment the IOP was decreased in all treated eyes for the duration of the study.

The presumed mechanism of action of this technique is decreased aqueous production secondary to destruction of the ciliary processes. Pathological examination of the treated eyes showed that, with our technique, the sclera was not affected, with the laser being very successfully focused on the ciliary processes. The only observed side effects in this study was a self resorbing hyphaema in 50% of the treated eyes.

Although the treatment appeared to be effective in lowering normal IOPs in rabbits, further studies are required to investigate the efficacy of this mode of treatment in humans with glaucoma. Cyrilin *et al.*⁷ have published preliminary results on human eyes. It appears that the technique is indeed of potential value in cases of uncontrolled IOP.

The recent availability of Nd-YAG lasers with the thermal mode option has created a widely available source of pulsed laser energy. Our results on rabbit eyes, taken in conjunction with preliminary results on human eyes, suggests that Nd-YAG cyclocoagulation may prove to be a new tool in the management of various types of glaucoma.

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