Histopathological characteristics of neodymium-YAG laser iridotomy in the human eye

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SUMMARY Light and electron microscopic studies of YAG laser iridotomies were performed in two human iridectomy specimens. Full-thickness defects were created and showed stromal and vascular necrosis. The light and electron microscopic configuration of the lesions was compatible with mechanical disruption from shockwaves. Thermal changes were absent in contrast to iridotomies created by argon laser photocoagulation.

Recent experience with Q-switched neodymium-YAG lasers suggests that photodisruption caused by plasma and shock-wave production is more effective than argon laser photocoagulation in creating permanent full-thickness iridotomies. We therefore examined the light and electron microscopic appearance of such iridotomies in two human eyes in order to understand the short-term effects of Q-switched photodisruption in the iris.

Materials and methods

Twenty-four hours prior to elective cataract surgery and after we obtained informed consent, neodymium-YAG laser iridotomies were created in two patients with light-brown irides. The first patient was a 74-year-old white woman whose best corrected visual acuity was 3/400. She had 3+ nuclear sclerosis and 3+ posterior subcapsular cataractous changes. Using the Lasag Microruptor II and the Lasag contact lens (CGI) with methylcellulose, we created a full-thickness iridotomy without haemorrhage in the superior portion of the iris (Fig. 1). Laser settings were 4-9 millijoules, with two pulse trains of four discharges aimed about 2 mm from the iris root. At the time of cataract extraction the involved sector of iris was removed for histological study.

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Fig. 1 Anterior segment photograph of the eye of patient 1 taken on the day of treatment. Neodymium-YAG laser iridotomy is marked by the arrow.
The second patient was a 62-year-old white woman who had diabetes for 40 years and was being treated with insulin. When initially seen three years before laser iridotomy she had prominent peripapillary rubeosis iridis and advanced epipapillary neovascularisation. The patient underwent panretinal photocoagulation at that time, and the rubeosis became much less prominent. Thereafter, progressive cataractous changes developed. Just prior to lens extraction the patient underwent Q-switched neodymium-YAG laser iridotomy with the Lasag Microruptor II. A contact lens (CGI) with methylcellulose was used. Two discharges of 6-0 millijoules with pulse trains of four discharges were directed at the iris, creating a full-thickness iridotomy. A tiny self-limited hyphaema occurred. The involved sector of iris was removed at the time of the cataract operation.

Results

Iris specimens from both patients were fixed by immersion in McDowell and Trumps fixative (1% glutaraldehyde and 4% paraformaldehyde), post-fixed in osmium tetroxide, dehydrated through graded alcohols, and embedded in Durcupan epoxy resin. Sections 1 μm thick were prepared with Mallory’s stain for light microscopy. Thin sections for transmission electron microscopy were stained with uranyl nitrate and lead citrate.

LIGHT MICROSCOPY

Both iris specimens (Figs. 2, 3) showed stromal necrosis in the areas of the full-thickness defects. Just peripheral to the necrotic regions were intact blood vessels. Within the areas of the laser induced defects the dilator muscles and pigment epithelia were absent. The tissue immediately surrounding the defects appeared totally necrotic, but more
Fig. 5  Electron micrograph of iris of patient 1 showing disruption of a blood vessel with extravasation of red blood cells (RBC), fibrinous deposits (F) in an occluded lumen, and pericytic degeneration (P). The endothelial cells (E) are bordered by basement membrane.

Fig. 6  Electron micrograph of iris of patient 1 showing cuboidal configuration of vascular endothelium (E); S = stroma; P = pericyte.
Fig. 7  Electron micrograph of iris of patient 1 showing dilator muscle (D) and pigment epithelial necrosis. A macrophage (M), which has phagocytised melanin granules, is present. The arrow points to phagosomes. Inset: Electron micrograph showing necrosis of the dilator muscle.

Fig. 8A: Electron micrograph of iris of patient 2 showing stromal cell lysis with rupture of plasma membrane and dispersion of cytoplasmic organelles (arrows). B: Electron micrograph illustrating pericytic degeneration. A lamellar body is seen in the pericyte (P). E=endothelial cell; L=lumen. Inset: Electron micrograph under higher magnification showing pericytic degeneration (P); L=lumen.
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ELECTRON MICROSCOPY
In the specimen from patient No. 1 there was lysis of stromal cells with rupture of the plasma membranes. The cytoplasm of these cells appeared watery (Fig. 4). Also noted were blood vessel disruption, extravasation of red blood cells, fibrinous deposits in occluded lumina, and pericytic degeneration (Fig. 5). Endothelial cells showed cuboidal configurations (Fig. 6). In addition the dilator muscle and pigment epithelium were necrotic. Macrophages were present and contained phagocytised melanin granules (Fig. 7).

In the iris specimen from patient No.2 stromal cells also showed lysis, with ruptured plasma membranes and dispersed cytoplasmic organelles (Fig. 8A). Pericytic degeneration was noted, and one pericyte contained a lamellar body (Fig. 8B). The pigment epithelium was swollen and showed rupture of plasma membranes and extrusion of melanin granules (Fig. 9). Dilator muscle necrosis was also observed in this specimen (Fig. 9, inset).

Discussion
Our findings confirmed theoretical considerations and prior observations in animals and humans regarding the shock-wave effects caused by the Q-switched neodymium-YAG laser. The histopathological alteration was compatible with mechanical disruption. Thermal, coagulative changes were absent, in contrast to iridotomies created by argon laser photocoagulation. Surprisingly little reaction surrounded the lesions (although a few macrophages were present), possibly due in part to the short-term nature of the observations.

The iris pigment epithelium appeared more severely disrupted than the stroma. It is possible that the loosely organised stroma is more resilient and able to withstand the shock-wave effects of the Q-switched explosion better than the taut pigment epithelium.
Vascular lesions consistent with mechanical rupture were also present. The lack of a thermal, coagulative effect is characteristic of Q-switched explosions and is associated, both clinically and microscopically, by extravasation of red blood cells. Such bleeding rarely has clinical significance.

Our data are compatible with those of prior investigators and confirm the value of the neodymium-YAG laser in creating full-thickness iridotomies. Damage to surrounding tissue is confined to the immediate area of the full-thickness defect. The lack of more peripheral damage may be important in minimising subsequent reparative efforts. Clinical experience suggests that iridotomies created with Q-switched explosions remain more open more often than do those characterised by the thermal denaturing effects of argon laser photo-coagulation. Iridotomies created by argon lasers usually require many more laser discharges than do those produced by neodymium-YAG lasers, and are associated with considerable inflammatory response. Fibroplasia is more likely to occur after argon laser iridotomy, and the rate at which iris openings become occluded is substantial. Neodymium-YAG lasers thus appear to be clinically more useful than argon lasers, because of their higher rate of persistently open iridotomies.

There are some risks to surrounding anterior segment structures when Q-switched explosions take place in the iris. Evidence indicates that micro-punctures of the anterior lens capsule may occur, though this rarely seems to cause progressive opacification of the entire human lens. In addition, if the iridotomy is created very close to the iris root, minor contiguous sites of damage occur in the corneal endothelium and trabecular meshwork. It is doubtful whether these events have clinically important sequelae, but long-term quantitative observations have not been made.

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