Laser trabeculoplasty

Early attempts at laser treatment of open angle glaucoma met with limited success. Gonipuncture using the Q-switched ruby laser caused a temporary reduction only of intraocular pressure (IOP), and argon laser photocagulation of the trabecular meshwork, though producing sustained IOP reductions in some patients, was accompanied by acute post-treatment rises in others. In 1979 Wise and Witter reported the successful reduction of IOP with few complications using the argon laser at lower energy levels than before. They treated the full circumference of the trabecular meshwork applying 100 evenly spaced burns of 50 μm spot size at a power of 1000 to 1500 mW for 0.1 seconds and achieved an average fall in IOP of 10-3 mm Hg at 3 months in 41 patients. This success was subsequently confirmed by others and the technique employed today is substantially the same.

Pathophysiology

Wise and Witter postulated that the fall in IOP was a mechanical effect, the evenly spaced microscars reducing the diameter of the inner trabecular ring and reversing collapse of the meshwork with restoration of normal outflow function. That argon laser trabeculoplasty (ALT) acts by increasing the fall of IOP has been supported by tonographic and fluorophotometric studies but this mechanical theory, though attractive, has not been supported by animal or enucleated human eye tissue studies. It has also been observed that heat induced shrinkage of the trabecular collagen is a rapid process whereas the time course of the ALT response is relatively slow. From early histological studies it was clear that successful argon laser treatment was not dependent on the formation of a direct communication between the anterior chamber and Schlemm's canal. Ultrastructural changes seen in trabeculotomy specimens from patients previously treated by ALT include intratrabecular debris, distortion of trabecular beams and death of trabecular endothelial cells, leaving the damaged beams denuded. But there is also evidence of activation and migration of surviving trabecular endothelial cells to the burn site. In many specimens cellular sheets extending from Schwalbe's line and covering the surface of the anterior meshwork have been observed. These sheets have been considered to represent an excessive repair response which contributes to failure of the laser treatment.

Increased trabecular cell division following ALT at sites distant to the laser burns has also been demonstrated in vitro using organ cultured trabecular meshworks, the majority of the cells originating in the anterior meshwork close to Schwalbe's line. Two weeks after laser treatment these active cells are concentrated around the burn sites and it has been suggested that they may exert an influence on outflow resistance by causing alterations in the synthesis of the proteoglycan components of the extracellular matrix. ALT causes a temporary disruption of the blood ocular barrier resulting in aqueous protein flare and there is evidence that this is mediated by prostaglandins which can be synthesised by the trabecular meshwork. Post-ALT flare is maximal at 48 hours and there is a positive correlation at this time between the level of inflammation and IOP decrease which can be partially blocked by prostaglandin synthesis inhibitors. Of particular interest is the finding of Mermod et al. that this correlation persists long after the inflammatory reaction has subsided and they considered the possibility that prostaglandin production might persist at a level sufficient to lower the IOP but too low to disrupt the blood ocular barrier.

Technique

The main treatment variables are the proportion of the angle treated, the size and placement of individual burns, and the energy used. Surprisingly, wavelength appears to be of little importance. No difference between the effect of argon blue-green and argon green lasers has been found and the krypton laser, the diode laser and others have all produced results comparable with those of argon.

Treatment of 180 degrees with 50 burns has been found by some investigators to be as effective as full 360 degree treatment while producing significantly lower post-treatment IOP rises. Others have achieved greater effect with 360 degree treatment but this can be more safely carried out in two treatment sessions of 180 degrees each.

The degree of IOP reduction is similar whether burns are placed on the anterior or posterior meshwork but acute IOP elevation has been correlated with sites of microperforation with ALT and there is growing evidence that ALT is more frequent with posterior placement. The accuracy of placement is facilitated by a small spot size and 50 μm has been almost universally used but Sherwood et al. using 150 μm and 350 μm spots obtained good pressure reduction though the larger spot was difficult to focus.

The effectiveness of ALT is independent of the duration of the burn if the total energy delivered is kept constant. With a duration of 0.1 seconds the effective power range lies between 500 mW and 1000 mW, lower than that originally used by Wise and Witter. Most authorities advocate adjusting the power level to obtain the minimum visible response of Blanching of the meshwork and/or gas bubble formation.

Complications

The most serious complication of ALT is post-treatment acute elevation of IOP resulting in loss of vision. Some increase in IOP is very common and in one study a rise of more than 5 mm Hg occurred in 34% and of more than 10 mm Hg in 12% of patients who had undergone 180 degree ALT. The frequency and severity of IOP elevations are increased by the use of higher energy levels, 360 degree treatment, posterior placement of burns, angle pigmentation, and a low preoperative facility of outflow. Most post-treatment IOP peaks occur within the first 2 hours but occasionally rises may be delayed and monitoring of IOP for 4 hours has been recommended. The cause of this IOP rise is uncertain but may result from swelling of the trabecular meshwork or obstruction of the trabecular spaces by debris. It is not prevented by steroids or antiglaucomatous but aqueous suppressants and miotics are effective as is apraclonidine, an α2 agonist, which has been found to reduce the incidence of all pressure rises by nearly two thirds and to eliminate all increases greater than 10 mm Hg.

PAS develop in a high percentage of patients undergoing ALT but these appear to be of little clinical significance and
are not associated with a reduced IOP response. They develop more frequently with posteriorly placed burns and with higher power levels.  

Other complications are relatively minor. Corneal endothelial damage has been reported but prospective studies have failed to show any evidence of morphological or functional damage and epithelial burns caused by focusing are transient. Similarly uveitis is usually mild and transient but post-treatment topical steroids are often prescribed routinely.

Results of treatment

ALT significantly reduces IOP in the short term. In one large study a reduction of 6-4 mm Hg (26%) was found at 5 months in 237 patients with primary open angle glaucoma (POAG) on maximum medical treatment.  

A greater reduction was obtained using ALT as the primary treatment with a fall of 9-0 mm Hg (33%) at 3 months in 264 patients with POAG.  

Several studies have also shown a beneficial effect of ALT on the diurnal pressure curve with marked reductions of individual IOP fluctuation in successfully treated patients.  

From the outset it was recognised that there was some loss of effect of ALT with time. By the mid 1980s it was evident that this loss was considerable. Schwartz et al found that their success rate of 77% at 2 years had fallen to 46% at 5 years and Spaeth and Baez have reported that only one third of their patients with POAG could be considered successfully treated by ALT after 5 years.  

Overall failure is highest in the first year and subsequently occurs at a rate approaching 10% per year. Retreatment of failed eyes that have undergone 360 degree ALT is significantly less successful than with initial treatment and loss of effect is more rapid. Richter et al retreated eyes that had undergone 180 degree ALT and achieved an IOP reduction of more than 3 mm Hg in only one third of eyes.  

The success of ALT is influenced by patient selection. Patients under 50 years of age respond less well but there is no difference between the sexes. Black patients initially do as well as white patients but loss of effect is more rapid with only half as many black patients considered successful after 5 years. Survival curve analysis has shown the median time to an IOP of 21 mm Hg to be 12 months for black patients and 60 months for whites.

The average initial fall in IOP of eyes with POAG is about 30%. The response is more or less linear with the pre-treatment pressure and, as might be expected, eyes with normal tension glaucoma show a smaller effect. The results of ALT in pigmentary glaucoma are conflicting with some evidence that older patients do less well, but overall the response is similar to that of POAG. The largest pressure reductions are seen in eyes with exfoliative glaucoma but there is some evidence that failure occurs earlier than in eyes with POAG and the pressure rise may be quite rapid. Other forms of secondary open angle glaucoma generally respond less well with uveitic and developmental glaucomas often showing little or no useful fall in IOP.

The role of ALT in the management of open angle glaucoma

Laser trabeculoplasty is an outpatient procedure that is well tolerated and relatively safe. It avoids the inconvenience and side effects of medical treatment and the risks of major intraocular surgery. But it also has drawbacks, the greatest of which is the loss of effect with time. Concern has also been raised about the possible adverse effect of ALT on subsequent drainage surgery. The incidence of encapsulated blebs has been found to be up to three times higher in eyes previously treated with ALT.

For a number of years ALT was considered to be a logical next step in the management of open angle glaucoma when maximum tolerable medical treatment had failed to keep the IOP within 'normal' limits or prevent further field loss. ALT was regarded as successful for as long as surgery was delayed and in many studies this has been the criterion of success. More recently the role of ALT as a primary treatment in the management of POAG has been investigated and compared in a number of studies with both medical and surgical treatment.

Prospective trials comparing ALT with medical treatment have given results which appear to favour laser treatment but which must be interpreted with caution. The use of stepped medical regimens and the addition of medications to the treatment of uncontrolled 'laser first' patients makes longer term comparison of the two modalities difficult if not impossible. The Glaucoma Laser Trial Research Group reported in 1990 the results of their laser versus topical medications trial. These showed a higher percentage of patients controlled by ALT alone at 1 and 2 years (63% and 44%) than by timolol alone (41% and 30%). But using any two of three allowed topical medications (timolol, dipivefrin, and pilocarpine) 85% and 66% of 'medical' eyes were controlled at 1 and 2 years respectively. The distinction between the two treatments becomes blurred when topical medications are added to failed ALT eyes and it is not easy to draw any firm conclusions. One could argue from the results that at 1 and 2 years medical therapy is better than ALT but the advantage probably lies with those patients who had ALT first because they were likely to avoid miotic therapy and its disadvantages for longer than those starting with timolol.

The advantages of surgery over ALT in controlling IOP are more clear cut. Both Watson et al and Migdal and Hitchings have confirmed the significantly lower pressures that can be achieved with trabeculectomy and the reduced need for subsequent medication.

Summary

Using the now well established technique ALT is a safe and effective means of lowering IOP in eyes with POAG, pigmentary glaucoma, and exfoliative glaucoma though the effect diminishes with time. Pressure reduction with ALT is seldom greater than 30% and eyes with an IOP of more than 28 mm Hg are unlikely to be controlled for any length of time without additional treatment. ALT is probably most suitable either for older patients whose glaucoma is not well controlled on medical treatment, or for patients with newly diagnosed open angle glaucoma, but without advanced field loss, as a primary treatment or in combination with a non-miotic topical medication. In many it will defer surgery, in some indefinitely.

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