Real-time control
for transscleral cyclophotocoagulation

Abstract  • Background: In transscleral cyclophotocoagulation, the surgeon cannot directly observe the applied laser effects. Overdosage, possibly resulting in unwanted pop effects, or underdosage with no therapeutic effect therefore often occur.

• Method and materials: Laser radiation passing through the sclera and ciliary body is partly reflected from the fundus and can be monitored from outside the eye by a detector system. Since all other parameters influencing the intensity of the recorded radiation are constant in time during one laser exposure, the time dependence of this radiation directly reflects the change of transmission of the treated tissue. The laser exposure therefore can be stopped by a computer when certain criteria of the recorded curves are fulfilled. In addition, the transmission curves are displayed on a monitor in real time, permitting the surgeon to interrupt the exposure. A Nd:YAG laser and a diode laser are connected to the device. After successful tests in enucleated porcine eyes which were evaluated histologically and in human cadaver eyes this method is applied to patients suffering from refractory glaucoma.

• Results: The transmission curves from enucleated porcine eyes show that the 810-nm diode laser is more appropriate for this method than the 1064-nm Nd:YAG laser, because the radiation output of the diode is more stable in time and the tissue absorption is higher, both resulting in a larger dynamical range of useful signal. The curves from the porcine eyes, the human cadaver eyes and the curves from patients show a typical shape which allows interruption of exposure either by the surgeon or by the computer program before a pop effect occurs.

• Conclusions: This new method increases the precision and safety of transscleral cyclophotocoagulation.

Introduction

Though transscleral cyclophotocoagulation using Nd:YAG continuous wave laser (e.g. [6, 16]) was first described more than 20 years ago [2] as a therapy for glaucoma, this method is still limited to severe, uncontrolled cases (e.g. [8, 18, 43]). Apart from the Nd:YAG laser, xenon arc lamps [38], the ruby laser [3], the krypton laser [20] and the diode laser [7, 15, 17, 19] have been applied to patients. The therapy was improved by the introduction of contact methods [11]; however, efforts undertaken so far to optimize therapy parameters [1, 10, 22, 29, 32, 36] could not solve the principal problem that the laser burns cannot be observed directly.

In addition, there is strong intra- and interindividual variation of optical properties of the corresponding tissue [9]. Therefore, standardization of therapy parameters such as irradiance and exposure time cannot lead to satisfactory results. Severe damage [24, 33] up to transient complete visual loss [14] with poor recovery has been observed. For this reason, although transscleral cyclophoto-
coagulation has some advantages [35], it has not yet been proven that this method is generally superior to the other therapy in intractable glaucoma, cyclocryocoagulation (e.g. [25, 31]).

An improvement of cyclophotocoagulation can only be achieved if it is possible to observe the coagulation of the target tissue (ciliary body), and to stop the laser immediately if coagulation is sufficient, particularly before the tissue evaporates, causing a so called pop effect.

Preferably, control of coagulation should be automatically performed by a computer, as demonstrated in patients [28] for retinal laser therapy.

Theoretical and experimental investigations in animals and criteria for automatic exposure control for retinal laser coagulation by measuring the reflectivity of the coagulated tissue have been described previously also by other authors [4, 5, 12, 21, 26, 39-42].

In the investigations mentioned, the coagulated tissue must be visible, because it is the tissue reflectivity that is dependent on time. It will be described in the next section, how the problem can be solved also for the ciliary body, which is normally not directly visible [27].

**Method and materials**

Controlling device

During coagulation, chemical and physical effects are induced, changing the optical properties of the tissue, i.e. the transmission, absorption and reflection. For the ciliary body, this effect cannot be observed directly. However, the transmitted radiation produces diffuse stray light which is partly reflected from the fundus and can be observed from outside the eye by a sensor. The principle of the device based thereon is illustrated in Fig. 1. The light intensity monitored by the sensor during the laser exposure depends on a lot of parameters (fundus reflectivity, pupil width, etc.) and can therefore not be used directly as an absolute measure of the coagulation stage of the tissue. However, the coagulation process changes the light observed as function of time in any case. Therefore, this time dependence can be used to monitor the progress of coagulation. The electronic signal has to be normalized to its starting value, i.e., only relative values are used for further evaluation.

Controlling of the process can be done in two ways. First, the surgeon can interrupt the exposure if the displayed curve of changing transmission has a certain shape. This is possible, but difficult, because typical time scales are in the range of 0.3–1 s, which is close to the surgeon’s own reaction time.

In order to display the signal on the full screen in all cases, first the laser is switched on for a short period (5 ms), and then the scale is adjusted correspondingly.

As a second “operator”, the computer can interrupt the exposure, in principle as described in [28]. Criteria for interruption are discussed below.

**Lasers**

For investigations in porcine eyes we first used a 1064-nm Nd:YAG laser (Microruptor III, Lasag/Meridian, Bern, Switzerland) giving a CW power of up to 10 W. Since this laser was not suitable for the method described here (see below), we constructed an 810 nm diode...