Efficacy and Safety of Repeated Ultrasound Cycloplasty Procedures in Patients With Early or Delayed Failure After a First Procedure

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Precis: Repeated ultrasound cycloplasty (UCP) procedures are valuable options in patients with early or delayed intraocular pressure (IOP) increase after a first procedure. The safety of a second procedure is similar to that of the first one.

Purpose: The purpose of this study was to evaluate the efficacy and safety of repeated UCPs in patients with early or delayed IOP increase after a first procedure.

Patients and Methods: Thirty-one eyes with open-angle glaucoma, with an IOP decrease, > 20% after a first UCP procedure (1 and/or 2 mo visit), and with an early or delayed IOP increase (IOP decrease < 20% compared with baseline before or after the first 6 mo, respectively), underwent a second UCP procedure. Examinations were performed at 1 day, 1 week, 1, 2, 3, 6, and 12 months. Primary outcomes were surgical success (IOP reduction ≥ 20% and IOP > 5 mm Hg) at the last follow-up and vision-threatening complications. Secondary outcomes were mean IOP at each visit, medication use, and other surgical interventions.

Results: In the group with early IOP increase, IOP was reduced ($P < 0.05$) from a mean value of 29.8 ± 8.2 mm Hg before retreatment (n = 3.3 medications) to 18.5 ± 7.4 mm Hg at the last follow-up (n = 3.5 medications) (−34%). Success was achieved in 52.6% of eyes (10/19) at the last follow-up visit. In the late IOP increase group, IOP was reduced ($P < 0.05$) from a mean value of 31.9 ± 6.6 mm Hg before retreatment (n = 4.0 medications) to 16.2 ± 5.2 mm Hg at the last follow-up (n = 4.0 medications) (−43%). Success was achieved in 55.5% of eyes (5/9) at the last follow-up visit. No major intraoperative or postoperative complications occurred.

Conclusion: A second UCP procedure could be considered in subjects with early or delayed failure after a first procedure.

Key Words: glaucoma, ultrasound, ciliary body, cycloplasty

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All treatments for glaucoma aim to reduce intraocular pressure (IOP) and can, therefore, have 2 mechanisms of action: reducing aqueous humor production via partial destruction or medical inhibition of the ciliary body or facilitating the evacuation of aqueous humor from the eye with drugs, lasers, or filtering surgery. Many physical methods have been proposed to partially destroy the ciliary body, and they result in coagulation necrosis of the ciliary body following heating (laser, ultrasound) or freezing (cryotherapy).

These cyclodestructive methods have 2 major drawbacks that limit their use: they are nonselective for the target tissue to be treated, often resulting in damage to adjacent structures, and they have an unpredictable dose-effect relationship, which prevents accurate prediction of the treatment effect.[1–8] Undertreatment leads to insufficient IOP reduction, and repetition of treatment may be required. As a result, these cyclodestructive methods are effective but poorly tolerated and are currently generally reserved for treating refractory glaucoma.

To overcome the drawbacks of cyclodestruction, a device was developed in the last decade that uses breakthroughs in the field of high-intensity focused ultrasound (HIFU) technology and aims to achieve selective and precise coagulation of the ciliary body while sparing the adjacent ocular structures.[9–15]

The specific advantage of HIFU is that the energy can be focused through nonoptically transparent media with controlled energy absorption, thus reducing the effects on the adjacent tissues. Similarly, energy deposition and tissue heating at the focus site do not depend on tissue pigmentation, which may vary greatly, particularly in the ciliary body.

A circular device including multiple transducers was developed to achieve a rapid, selective, and 1-step coagulation of the ciliary body, without displacement of the device during the procedure.[10] The device is composed of 2 parts: a coupling cone made of polymer, which is placed in direct contact with the eye, allowing good positioning of the transducers in terms of centering and distance (Fig. 1), and a ring containing 6 active piezoelectric transducers, operating at a frequency of 21 MHz, which is then inserted on the coupling cone.

Experimental and clinical studies have suggested that HIFU treatment of the ciliary body decreases IOP both by reducing aqueous humor production and by facilitating the aqueous outflow. Histologic examinations and scanning electron microscopy have found a selective and circumferentially distributed coagulation necrosis of the ciliary processes and ciliary body, with a loss of the ciliary epithelium.[9] Corrosion casts revealed focal interruption of the ciliary body and pars plana microvasculature. Experimental studies in animals and ultrasound biomicroscopic (UBM) studies in humans have shown sustained fluid spaces between the sclera and the ciliary body and between the sclera and the choroid adjacent to treated areas but not adjacent to untreated areas.[15]

Several clinical studies and series have evaluated the efficacy and safety of a single ultrasound cycloplasty (UCP) procedure.[11,13,15] To date, only 1 study focused on the efficacy and safety of multiple UCP procedures.[16] It evaluated

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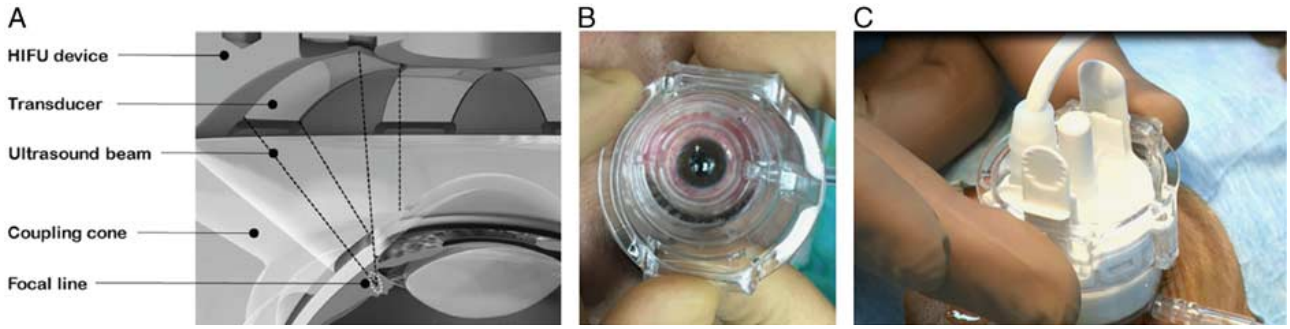

FIGURE 1. A, A piezoceramic transducer with a cylindrical segment enabling the ultrasound beam to be focused on the ciliary body. B, Placement and centering of the coupling cone. C, Probe inserted in the coupling cone; the cavity is filled with saline solution. HIFU indicates high-intensity focused ultrasound.

the effects of a second and possibly third procedure in patients who responded to a first procedure but in whom the target IOP was not reached.

In the present study, we aimed to evaluate the efficacy and safety of a second UCP procedure in patients who demonstrated a significant IOP decrease after a first procedure but then presented an early or a delayed IOP increase.

PATIENTS AND METHODS

This study was designed, conducted, and reported according to the World Glaucoma Association guidelines on the design and reporting of glaucoma surgical trials.[17]

Patients

We conducted this study in a cohort of glaucoma subjects aged 18 years or older who had undergone a UCP procedure from April 2015 and were followed up in 2 university-affiliated glaucoma centers (Grenoble and Lille University Hospitals, France). The study protocol was approved by an institutional review board (Auvergne-Rhône-Alpes, France) and the health regulatory authority. All patients provided both verbal and written informed consent before inclusion in the study. The study followed the tenets of the Declaration of Helsinki and was conformed to ISO 14155 standards (Clinical Investigation of Medical Devices for Human Subjects).

All patients were followed up after the procedure at day 7, months 1, 2, 3, and then semiannually. A total of 141 subjects were included in the cohort. Male or female patients who met the following criteria were eligible for inclusion in the study, and their data were extracted from the cohort data: aged over 18 years; diagnosis of primary or secondary open-angle glaucoma; average baseline IOP $\geq$21 mm Hg while on maximum tolerated medical treatment before the first UCP procedure; treated with an UCP procedure and followed according to the defined follow-up visit calendar after the first procedure; IOP decrease $>$20% after the first UCP procedure (1 and/or 2 mo visit) and with an early (group 1) or delayed IOP increase (group 2). Early IOP increase was defined as an IOP decrease $<$20% compared with baseline at 3 and/or 6 months. Delayed IOP increase was defined as an IOP decrease $<$20% compared with baseline after the first 6 months of follow-up. Data extraction was performed in April 2019.

Exclusion criteria were as follows: pregnancy; concomitant systemic medications that could affect IOP; diagnosis of normal-tension glaucoma; history of refractive surgery, retinal detachment or ocular tumor; intraocular surgery (except uncomplicated cataract surgery) within the previous 12 months; laser trabeculoplasty within the previous 3 months; and ocular infection in the previous 2 weeks.

UCP Procedure and Follow-up

The ultrasound procedure was similar in the 2 centers and for all patients included in the cohort. The ultrasound device has been previously described in detail.[9,10] A coupling cone made of the polymer was placed in direct contact with the eye, which allows good placement of the transducers in terms of centration and distance. At the base of the coupling cone, a suction ring allowed the application of a low-level vacuum and enabled the cone to maintain contact with the eye. A 30 mm diameter, 15 mm high ring containing 6 active piezoelectric elements was inserted in the upper part of the coupling cone. The cavity created between the eye, the cone, and the probe (4 mL) was filled with saline solution (BSS; Alcon Inc., Fort Worth, TX) at room temperature. Three device models with different ring diameters, equipped with the 6 transducers, were available. Depending on the diameter, the 6 elliptical cylinder-shaped impacts were centered on an 11, 12, or 13 mm diameter circle and spread over the circumference of the eye while avoiding the nasal-temporal meridian. In each patient, the ring model whose focal zones matched the ciliary body was determined at baseline by UBM imaging of the anterior segment. The location of the focal zones was simulated using the UBM images, and the model that best targeted the ciliary body was chosen.[11]

Baseline evaluation included best-corrected visual acuity, slit-lamp biomicroscopy with gonioscopy and mydriatic fundus examination, Goldmann applanation tonometry with three measurements, ultrasound pachymetry, visual field, UBM imaging of the anterior segment, and macular and optic nerve head optical coherence tomography (OCT) examinations. The visual field was examined using an automated diagnostic system (Humphrey Field Analyzer; 24-2 SITA-standard program; Carl Zeiss Meditec, Dublin, CA), UBM with a 50 MHz probe (Aviso; Quantel Medical, Clermont-Ferrand, France) and OCT with a Cirrus OCT (Carl Zeiss Meditec). For UBM, radial and transverse scans were obtained at 0, 45, 90, 135, 180, 225, 270, and 315 degrees' meridians.[11]

The HIFU procedures were performed by 2 authors (F.A. and J.-F.R.) under peribulbar or general anesthesia, depending on patient and physician preferences. The following parameters were used: operating frequency, 21 MHz; the number of sectors activated, 6; acoustic power, 2.45 W;

TABLE 1. Demographic and Ocular Characteristics of the Population

	Mean ± SD (Range)/n (%)		
	All Subjects (N = 31)	**Group 1 "Early IOP Increase" (N = 22)**	**Group 2 "Late IOP Increase" (N = 9)**
Age	61.8 ± 13.4 (18-80)	60.6 ± 15.1 (18-80)	64.7 ± 8.1 (55-78)
Sex (male/female)	17/14	13/9	4/5
Glaucoma type			
Primary OAG	24 (77.4)	17 (77.3)	7 (77.8)
Pigmentary glaucoma	2 (6.5)	2 (9.1)	
Juvenile glaucoma (n = 3)	3 (9.7)	3 (13.6)	
Myopic glaucoma (n = 2)	2 (6.5)		2 (22.2)
Previous ocular treatments			
Laser trabeculoplasty	9 (29)	8 (36.4)	1 (11.1)
Stent/tube			
Trabeculectomy	9 (29)	7 (31.8)	2 (22.2)
NPGS	10 (32.3)	6 (27.3)	4 (44.4)
Diode CPC	1 (3.2)	1 (4.5)	
Pseudophakic	10 (32.3)	5 (22.7)	5 (55.6)
IOP before the second UCP	32.7 ± 9.1 (18-50)	33 ± 9.2 (18-50)	31.8 ± 9.2 (18-50)
No. hypotensive medications before the second UCP	3.3 ± 0.7 (2-4)	3.4 ± 0.7 (2-4)	3.2 ± 0.7 (2-4)

CPC indicates cyclophotocoagulation; IOP, intraocular pressure; NPGS, nonpenetrating glaucoma surgery; OAG, open-angle glaucoma; UCP, ultrasound cycloplasty.

duration of each of the 6 shots, 8 seconds; and time between each shot, 20 seconds. Postoperatively, patients were treated topically with tobramycin and dexamethasone (Tobradex; Alcon Inc.), 4 times a day for 4 weeks. Preoperative hypotensive medications were maintained unchanged throughout the course of the study, without any washout period before the baseline IOP measurements.

Follow-up

After the second UCP procedure, best-corrected visual acuity, slit-lamp biomicroscopy with mydriatic fundus examination, and Goldmann applanation tonometry were performed at 1 day, 1 week, and 1, 2, 3, 6, and 12 months. All IOP measurements were taken at the same time of day as the preoperative IOPs. Visual field examination was performed at 12 months.

Endpoints and Statistical Analysis

Primary outcomes were a surgical success (defined as IOP reduction from baseline ≥ 20% and IOP > 5 mm Hg) at the last follow-up visit and vision-threatening complications. Vision-threatening complications were the number of standardized severe complications defined in the World Glaucoma Association guidelines on the design and reporting of glaucoma surgical trials.[17] Secondary outcomes were mean IOP at each follow-up visit compared with baseline, medication use, complications, and other surgical interventions.

The Skewness-Kurtosis normality test was used to assess the normality of the IOP measurements. A paired *t* test was used to compare means. Statistical significance was set at *P*-value <0.05. Statistical software (SPSS, version 17.0; SPSS Inc., Chicago, IL) was used for data analysis.

RESULTS

Patient Characteristics

Patients' characteristics are summarized in Table 1. Thirty-one patients underwent a second UCP procedure, 22 in group 1 and 9 in group 2.

Efficacy

IOP values and absolute and relative IOP reductions from baseline at the follow-up visits are given in Table 2. Graphs showing IOP reduction in groups 1 and 2 over time are displayed in Figure 2.

In group 1 (early IOP increase), IOP was significantly reduced ($P < 0.05$) from a mean value of 29.8 ± 8.2 mm Hg before retreatment (n = 3.3 hypotensive medications) to

TABLE 2. IOP at Baseline and During Follow-up in the 2 Groups

	Group 1 "Early IOP Increase"		Group 2 "Late IOP Increase"	
	IOP (Mean ± SD)	**Relative IOP Reduction (%)**	**IOP (Mean ± SD)**	**Relative IOP Reduction (%)**
First UCP	33.0 ± 9.2	—	31.8 ± 8.9	—
Month 1 after first UCP	24.1 ± 12.2	29	23.0 ± 7.8	23
Month 6 after first UCP	—	—	21.7 ± 12.0	32
Before the second UCP	29.8 ± 8.2	—	31.9 ± 6.6	—
Month 1 after second UCP	19.5 ± 10.9	34	22.8 ± 6.7	28
Last follow-up	18.5 ± 7.4	34	16.2 ± 5.2	43

IOP indicates intraocular pressure; UCP, ultrasound cycloplasty.

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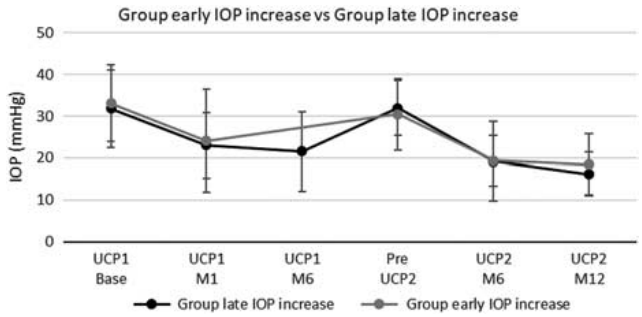

FIGURE 2. Graph showing IOP reduction (mean ± SD) over time. IOP indicates intraocular pressure; UCP, ultrasound cycloplasty.

18.5 ± 7.4 mm Hg at the last follow-up (n = 3.5 hypotensive medications) (mean IOP reduction of 34%). Success was achieved in 52.6% of eyes (10/19) at the last follow-up visit (mean IOP reduction of 40%). A total of 3 patients were lost to follow-up before the 6-month visit after the second UCP procedure, and 7 patients required an additional glaucoma surgical intervention (trabeculectomy in 2 patients and a third UCP procedure in 5 patients) due to insufficient response to the HIFU treatment. These interventions occurred within 6 months after the HIFU procedure. The study design stated that if an additional treatment such as filtering surgery or cyclodestruction was administered, the patient would be considered as having failed the HIFU treatment (failure) and would be withdrawn from the study. Thus, efficacy data (IOP values) were not collected and integrated into the results for the patients withdrawn from the study after undergoing filtering surgery or a third UCP procedure.

In group 2 (late IOP increase), IOP was significantly reduced ($P < 0.05$) from a mean value of 31.9 ± 6.6 mm Hg before retreatment (n = 4.0 hypotensive medications) to 16.2 ± 5.2 mm Hg at the last follow-up (n = 4.0 hypotensive medications) (mean IOP reduction of 43%). Success was achieved in 55.5% of eyes (5/9) at the last follow-up visit (mean IOP reduction of 43%). Three patients required a secondary glaucoma surgical intervention (trabeculectomy in 2 patients, and a third UCP procedure in 1 patient) for insufficient response to HIFU treatment. These patients were considered failures. No patient was lost to follow-up.

Safety

No complications occurred during any of the procedures. The postoperative complications observed are listed in Table 3. No case of severe hypotony (IOP ≤ 5 mm Hg) or ocular phthisis occurred.

The mean visual acuity of all patients included was reduced after the second UCP procedure compared with baseline: 0.85 (0 to 2.3) logMAR before the first UCP, 1.31 (0 to 2.5) logMAR before the second treatment, and 1.52 (0 to 2.6) logMAR for the last value at the end of the follow-up ($P < 0.01$). In group 1, these values were 0.72 (0 to 2.3) logMAR, 1.03 (0 to 2.5) logMAR, 1.47 (0 to 2.6) logMAR, respectively. In group 2, these values were 0.99 (0 to 2.3) logMAR, 1.59 (0.3 to 2.5) logMAR, 1.56 (0.2 to 2.5) logMAR, respectively.

A reduction in visual acuity of 0.2 logMAR or more between baseline and the last follow-up visit occurred in 9/31 subjects. The reasons reported by the investigators were as follows: high IOP and glaucoma progression (n = 3 subjects), cataract progression (n = 3), corneal edema (n = 2), and chronic superficial punctate keratitis (n = 1).

DISCUSSION

Statement of Principal Findings

This study was conducted to evaluate the efficacy and safety of repeated UCP procedures in patients with early or delayed IOP increase after a first procedure. From a cohort of open-angle glaucoma subjects treated with an UCP and followed-up according to a fixed follow-up visit calendar, 31 eyes of 31 patients with a significant IOP decrease after a first UCP procedure required a second UCP procedure because of an early (before 6 mo of follow-up) or late (after 6 mo of follow-up) increase in IOP. The baseline mean IOP was similar in both groups (group 1: 33.0 ± 9.2 mm Hg and group 2: 31.8 ± 8.9 mm Hg). A significant IOP reduction occurred in each group after the first procedure, 24.1 ± 12.2 and 23.0 ± 7.8 mm Hg after 1 month of follow-up, respectively. The mean IOP before the second procedure was similar in both groups (group 1: 29.8 ± 8.2 mm Hg and group 2: 31.9 ± 6.6 mm Hg). After the second UCP procedure, the mean IOP reduction was substantial and sustained in both groups, with an IOP reduction of 11.3 ± 8.7 mm Hg (group 1) and 13.7 ± 10.1 mm Hg (group 2) at the last follow-up visit. The tolerability of the second UCP procedure was similar to the first UCP procedure.

In Comparison With Other Studies

Several clinical studies have been conducted to evaluate the efficacy and safety of the new ultrasonic ciliary body coagulation device. Most of the studies were prospective series of patients with filtering surgery–naive glaucoma or refractory glaucoma who underwent a single UCP procedure. Table 4 shows a summary of the results of previously published studies in terms of the ability to reduce the

TABLE 3. Details of Postoperative Complications

	n/N (%)		
Descriptions	**Population**	**Group 1 "Early IOP Increase"**	**Group 2 "Late IOP Increase"**
Superficial punctate keratitis	27/31 (87)	19/22 (86)	8/9 (89)
Mydriasis	12/31 (39)	10/22 (46)	2/9 (22)
Conjunctival hyperhemia	7/31 (23)	6/22 (27)	1/9 (11)
Transient hypotony (IOP < 10 mm Hg)	3/31 (10)	3/22 (14)	0/9 (0)
Scleral thinning	2/31 (7)	2/22 (9)	0/9 (0)
Corneal edema	2/31 (6)	1/22 (4)	1/9 (11)

IOP indicates intraocular pressure.

TABLE 4. Success Rates of UCP Procedures in the Literature

References	No. Subjects	Glaucoma Type	Follow-up	Methods	Efficacy Results	Success Rate (% All Population)	Mean IOP Reduction (% All Population)
Aptel et al[11]	12	Refractory	12	Prospective multicenter	IOP baseline = 37.9 ± 10.7 mm Hg (3.4 medications) IOP month 12 = 24.7 ± 8.5 mm Hg (3.2 medications)	83.3	33.9
Aptel et al[14]	28	Refractory	12	Prospective multicenter	IOP baseline = 29.0 ± 7.2 mm Hg (3.8 medications) IOP month 12 = 21.6 ± 9.4 mm Hg (3.8 medications)	50	26
Denis et al[13]	52	Refractory	12	Prospective multicenter	IOP baseline = 29.0 ± 7.4 mm Hg IOP month 12 = 18.5 ± 6.6 mm Hg	48	36
Melamed et al[18]	20	Refractory	12	Prospective single center	IOP baseline = 36.4 ± 5.7 mm Hg (4.6 medications) IOP month 12 = 22.5 ± 10.3 mm Hg (4.0 medications)	45	38
Aptel et al[19]	30	Nonrefractory	12	Prospective multicenter	IOP baseline = 28.2 ± 7.2 mm Hg (3.6 medications) IOP month 12 = 19.6 ± 7.9 mm Hg (3.1 medications)	47	30
Giannaccare et al[20]	30	Refractory +nonrefractory	6	Prospective single center	IOP baseline = 30.1 ± 10.5 mm Hg (2.7 medications) IOP month 6 = 20.2 ± 6.2 mm Hg (2.0 medications)	70	33
De Gregorio et al[16]	40	Refractory +nonrefractory	12	Prospective single center	IOP baseline = 32.5 ± 9.9 mm Hg IOP reduction at month 12 = 34%-45%	85 (multiple UCP)	35
Giannaccare et al[21]	49	Refractory	12	Prospective multicenter	IOP baseline = 27.7 ± 9.2 mm Hg IOP month 12 = 19.8 ± 6.9 mm Hg	75	29
Deb-Joardar and Reddy[22]	73	Nonrefractory	12	Prospective single center	IOP baseline = 23.5 ± 3.0 mm Hg IOP month 12 = 15.7 ± 5.4 mm Hg	78	30
Pellegrini et al[23]	18	Refractory +nonrefractory	6	Prospective single center	IOP baseline = 26.8 ± 7.2 (3.2 medications) IOP month 6 = 14.7 ± 3.4 mm Hg (2.3 medications)	ND	45

IOP indicates intraocular pressure; ND, not documented; UCP, ultrasound cycloplasty.

IOP and success rates of UCP. A small proportion of patients with an insufficient IOP response to reach the target IOP after a first UCP procedure were retreated in 2 of the previous studies.[13,14] The 6 transducers of the device were activated, and the orientation of the device was unchanged (no rotation). In Denis et al,[13] 52 patients with open-angle or angle-closure glaucoma refractory to the filtering surgeries underwent 1 UCP procedure. After 2 months of follow-up, 8/52 patients were retreated on the basis of either the IOP remaining >28 mm Hg despite initial treatment efficacy (ie, a >20% reduction), or for a <20% decrease in IOP versus preoperative values. The diameter of the probe was generally changed for the second treatment (n = 3/8 eyes retreated without diameter change, 4/8 increased, 1/8 decreased), and 3/8 eyes demonstrated an IOP decrease >20% 6 months after the second treatment. In Aptel and colleagues, a study performed in 30 open-angle glaucoma patients naive of any previous glaucoma filtering surgery, 4 nonresponder patients were retreated during the first 3 months of follow-up using the same device size and location. Success was obtained in only 1 of the 4 patients retreated after 12 months of follow-up.[14]

The study reported by De Gregorio et al[16] was the first of its kind to specifically evaluate the effects of a second and possibly a third procedure in responder patients to a first procedure but in whom the target IOP was not reached. The protocol was, therefore, different from that of the present study. Patients with glaucoma that was uncontrolled with maximal medical therapy and IOP >21 mm Hg were included. After each UCP procedure, the treatment was repeated at 4 months if the IOP was >21 mm Hg without major complications, with up to 3 consecutive procedures in a given patient. The mean preoperative IOP was 32.5 ± 9.9 mm Hg. Four months after the first UCP treatment, the overall IOP reduction was 27.8% (n = 40 eyes). A second treatment was performed in 20 of these eyes. Four months after the second UCP procedure, IOP reduction was 20.3% from preoperative values and 34.7% from baseline. Twelve of the 20 retreated eyes underwent the third treatment. Four months after the third UCP treatment, overall IOP reduction was 34% and 52.6% from baseline. At 12 months, complete success was achieved in 85% (34/40) of treated eyes. This demonstrates that multiple UCP treatments have a cumulative effect on the IOP reduction and success rate with a good safety profile. It differs from our study, as we evaluated the effect of a second procedure in patients initially responsive to a first procedure but subsequently having an early or late IOP increase.

Meaning of the Study

The analysis of IOP evolution over time in both groups pointed out several features. Mean baseline IOP and demographic characteristics were similar in both groups, suggesting that pretreatment IOP and glaucoma type do not seem to be good parameters to predict the risk and timing of failure after the first procedure. Furthermore, 1 month after the first HIFU procedure, the IOP dropped significantly to a similar extent in each group. Thus, the short-term response to a first UCP procedure does not seem to be a potential predictor of the risk of early or late IOP increase.

The rate of responders and the magnitude of the IOP decrease after a second UCP procedure were significant in both groups, and the safety profile of the second procedure was similar to that reported in the literature after a first procedure (Table 4). This indicates that a second UCP procedure is a valuable option in subjects with early or delayed failure after a first procedure. This is of clinical interest, as the rate of failure after a first UCP is close to one third of patients treated, and as UCP is frequently performed in subjects with glaucoma refractory to the conventional glaucoma-filtering surgery, in whom the available therapeutic options could be limited. The results obtained in the present study corroborate those obtained by De Gregorio and colleagues showing a cumulative effect of repeated UCP procedures.

A limitation of the current study is that the surgical success criteria we chose—IOP reduction > 20% with possible retreatment—may be considered to be not very stringent. However, the same success criterion has been used in several previous glaucoma surgical trials, particularly in the three main clinical studies evaluating the new ultrasonic ciliary body coagulation device, and hence using the same criterion facilitates comparisons of treatment outcomes between studies.[11,13,14,17]

Unanswered Questions and Future Research

In the present study, the 6 transducers of the device were activated during the second procedure, and the orientation and size of the device were unchanged compared with the first procedure (no rotation). We hypothesize that the incremental reduction of IOP is due to an increase in the size and depth of the ciliary bodies' focal zone obtained during the first treatment. Further studies could evaluate the effects of retreatments performed with a different orientation and/or probe size. This would also augment the volume of ciliary body coagulated, but by creating several new focal zones instead of increasing the size of the previous focal zones. It has been suggested that failure after UCP treatment could be due to an incorrect preoperative calculation of the diameter of the probe to be used, leading to suboptimal targeting of the ciliary body by the ultrasound beam during the procedure.[14] This could constitute a rationale to change the orientation and size of the probe during a second procedure after a first unsuccessful procedure.

The present study used 6-sector probes that were available at the time of the study. New probes allowing the treatment of 2 additional sectors, that is, 8-sector probes, are now marketed in Europe. Future studies could evaluate the effect of retreatments performed with the new probes allowing the amount of tissue to be coagulated to be increased. This might be useful after a first failed or inadequately efficient procedure.

It should be mentioned that our patient follow-up after the second UCP procedure was 1 year, as per previously published studies carried out with UCP. Studies evaluating the effect of UCP with longer follow-up are needed. From the cohort of 141 subjects that were used to select subjects with a second treatment, we are currently analyzing the long-term effect of a first UCP procedure (3 y results), and the results should be reported soon.

CONCLUSION

This study shows that a second UCP procedure could be considered in subjects with early or late IOP increase after a first procedure and allows a sustained IOP decrease in a significant number of subjects who were retreated, with a safety profile comparable to that of the first procedure.

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