The distribution of ultrasound cyclo plasty probe models in Chinese glaucoma patients

Shaoyang Zheng
Zhongshan University Affiliated Eye Hospital: Sun Yat-Sen University Zhongshan Ophthalmic Center

Dingqiao Wang
Zhongshan University Affiliated Eye Hospital: Sun Yat-Sen University Zhongshan Ophthalmic Center

Zhihong Huang
Zhongshan University Affiliated Eye Hospital: Sun Yat-Sen University Zhongshan Ophthalmic Center

Liming Chen
Zhongshan University Affiliated Eye Hospital: Sun Yat-Sen University Zhongshan Ophthalmic Center

Zhixin Tang
Zhongshan University Affiliated Eye Hospital: Sun Yat-Sen University Zhongshan Ophthalmic Center

Huanling Hu
Zhongshan University Affiliated Eye Hospital: Sun Yat-Sen University Zhongshan Ophthalmic Center

Meng Hu
Zhongshan University Affiliated Eye Hospital: Sun Yat-Sen University Zhongshan Ophthalmic Center

Chengguo Zuo
Zhongshan University Affiliated Eye Hospital: Sun Yat-Sen University Zhongshan Ophthalmic Center

Mingkai Lin (linmk@mail.sysu.edu.cn)
Sun Yat-Sen University Zhongshan Ophthalmic Center

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Abstract

Purpose To investigate the distribution of ultrasound cyclo plasty (UCP) probe models in Chinese glaucoma patients.

Methods Patients need glaucoma surgery were recruited at Zhongshan Ophthalmic Center from January 2019 to December 2019. Patient demographics were recorded and analyzed. Visual acuity, intraocular pressure (IOP), retinal nerve fiber layer (RNFL), mean defect of visual field (MD), ocular axial length (AL) and horizontal corneal diameter (white to white, WTW) of eyes with glaucoma were measured and the UCP probe models were calculated by the use of nomogram tool and two ocular anatomical parameters: WTW and AL.

Results 2000 eyes of 1281 patients were involved in this study, with 559 (43.64%) males and 722 (56.36%) females. The mean age is 61.43 ± 12.21 years old, ranged from 18 to 91. IOP ranged from 5.0 to 60.0 mmHg, with a mean of 20.07±10.71 mmHg. The mean AL and WTW are 22.96 ± 1.43 (ranged 19.07 to 35.00) and 11.55 ± 0.50 (ranged 9.6 to 13.7), respectively. According to the results calculated by nomogram tool, Chinese patients’ eyes are mainly adapted to the model 12, with a percentage of 69.05%. The model 13 and the model 11 are suitable for 26.65% and 3.35%, respectively. 0.95% of Chinese patients do not have a suitable probe model.

Conclusion For Chinese patients who need glaucoma surgery, UCP probe models are mainly distributed in the model 12, followed by the model 13 and model 11 is the least used.

Introduction

Glaucoma is the first leading cause of irreversibility blindness in the world [1]. It’s a chronic eye disease caused by progressive degeneration of the optic nerve due to multiple confounding factors, in which elevated intraocular pressure is recognized as one of the most important factors[2]. It has been recognized that the effect of filtration surgery depends on the condition of the conjunctiva and is troubled by scarring after filtration. Traditional surgery to reduce aqueous humor, such as cyclocryotherapy and cyclophotocoagulation, reduced the intraocular pressure by non-selective destruction of the ciliary body, could bring damage to the adjacent structures and then cause visual lose, ocular pain, phthisis, inflammation and other adverse effects[3–5].

Ultrasound cyclo plasty (UCP), as a noninvasive treatment, has been on the rise in recent years, benefiting from the development of focused ultrasound technology and the advent of EyeOP1[6, 7]. UCP procedure was registered in China in 2017. Studies have shown that this device utilizes high intensity focused ultrasound technology to cure glaucoma patients by partial coagulation necrosis of the ciliary body, with decent tolerance and curative effect[8–12]. Compared with the above surgical methods, the EyeOP1 treatment has the advantages of non-invasive, precise positioning, effectively reducing intraocular pressure, fewer complications and lower pain score[13–15]. In view of the current uncertain efficacy of
classic anti-glaucoma surgery and minimally invasive glaucoma surgery, many complications, long
operation time or high price, UCP is very likely to be applied to almost all types of glaucoma.

The ring treatment probe that produces and delivers the ultrasound and focus its energy on a focal point
has 3 different sizes to fit the eye. The design of the probe model is mainly based on the biological
characteristics of the eyes of European glaucoma populations. By measuring two ocular anatomical
parameters (AL and WTW) and using the nomogram tool, we could acquire the suitable probe model for
each patient[16].

However, there has been no studies on the distribution of the probe models in glaucoma patients
requiring this treatment yet and no studies to prove that the UCP probe model is suitable for the Chinese
population. There are a huge number of glaucoma patients in China. Since UCP surgery was registered in
China, the number of glaucoma patients who choose UCP treatment has been increasing year by year,
and more and more patients will choose UCP surgery in the future. It is urgent to explore the applicability
of the three models of probe of UCP equipment in Chinese glaucoma patients. So we conducted this
study investigated the distribution of ultrasound cycloplasty probe models in Chinese glaucoma patients
and explore if it is necessary to design more probe models to guide clinical and the UCP equipment
improvements.

**Methods**

**Patient Enrollment**

From January 2019 to December 2019, glaucoma patients who are suitable for UCP surgery and require
intraocular pressure reduction surgery at Zhongshan Ophthalmic Center in Guangzhou were recruited in
this study. This study was approved by the Human Research, Ethics Committee, Zhongshan Ophthalmic
Center, Sun Yat-sen University and adhered to the tenets of the Declaration of Helsinki. All of the
participants have undergone a baseline evaluation. It included BCVA (best-corrected visual acuity), IOP
measurement, Humphrey visual field test, a slit-lamp biomicroscopy, funduscopy, ultrasound
biomicroscopy and OCT (optical coherence tomography) measurement.

**Inclusion Criteria**

Inclusion criteria included patients at the age between 18 and 90 years old, with incontrollable intraocular
pressure by traditional glaucoma surgery or medications, having not received intraocular surgery or laser
treatment. Exclusion criteria included narrow palpebral fissures, hollow eyes, thyroid associated
ophthalmopathy, eye infections two weeks before surgery, aphakia, history of ciliary body surgery,
vitrectomy, staphyloma, intraocular tumor or retrobulbar tumor, pregnancy and any serious systemic
diseases.

**Device**
The procedure UCP, using HIFU as we have described, was performed with the device EyeOP1 developed by Eye Tech Care, Rillieux-la-Pape, France. It consists of two parts: a console with a foot switch and three models of sterile disposable EYEOP-PACK, which has a therapy probe and a positioning cone. The therapy probe has 6 transducers to generate 6 beams of focused ultrasound that induces ciliary body damage, causing partial coagulation and necrosis of the ciliary body. According to the diameter of the therapy probe (11-, 12- and 13-mm), EYEOP-PACK were called model 11, 12, 13, respectively.

**Statistical Analysis**

The UCP probe models were calculated by the use of nomogram tool which has been provided by the Eye Tech Care Company and two ocular anatomical parameters: WTW and AL. All of the data were recorded in Microsoft Excel spreadsheets, and then were analyzed using SPSS for Windows version 25 software (SPSS Inc., Chicago, IL, USA). Visual acuity, intraocular pressure (IOP), retinal nerve fiber layer (RNFL), mean defect of visual field (MD), ocular axial length (AL) and horizontal corneal diameter (white to white, WTW) were expressed as the mean ± standard deviation (SD) with the range.

**Results**

**Patient Characteristics**

Table 1 lists the characteristics of all of the glaucoma patients that participate in this study. 2000 eyes of 1281 patients were enrolled, with a mean age of 61.43 ± 12.21 years old. 559 (43.64%) of them are male and 722 (56.36%) of them are female. The statistic results of the measurements were also listed in Table 1. The mean IOP was 20.07 ± 10.71 mmHg, ranged from 5.0 to 60.0. The mean value of AL and WTW were 22.96 ± 1.43 and 11.55 ± 0.50, respectively. The participants were compromised of 7 types of glaucoma patients, and the distribution has been shown in Figure 1. According to Figure 1, most of the participants are patients with POAG or PACG. Patients with POAG and patients with PACG account for 21.08% and 58.00%, respectively.
## Table 1
Demographic and clinical characteristics of the glaucoma patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye / patients(n)</td>
<td>2000 / 1281</td>
</tr>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>Mean±SD</td>
<td>61.43 ± 12.21</td>
</tr>
<tr>
<td>Range</td>
<td>18, 91</td>
</tr>
<tr>
<td>Male / female sex</td>
<td>559/722</td>
</tr>
<tr>
<td>VA (logMAR values)</td>
<td></td>
</tr>
<tr>
<td>Mean±SD</td>
<td>0.74 ± 0.79</td>
</tr>
<tr>
<td>Range</td>
<td>-0.18, 3.00</td>
</tr>
<tr>
<td>IOP (mmHg)</td>
<td></td>
</tr>
<tr>
<td>Mean±SD</td>
<td>20.07 ± 10.71</td>
</tr>
<tr>
<td>Range</td>
<td>5.0, 60.0</td>
</tr>
<tr>
<td>AL (mm)</td>
<td></td>
</tr>
<tr>
<td>Mean±SD</td>
<td>22.96 ± 1.43</td>
</tr>
<tr>
<td>Range</td>
<td>19.07, 35.00</td>
</tr>
<tr>
<td>WTW (mm)</td>
<td></td>
</tr>
<tr>
<td>Mean±SD</td>
<td>11.55 ± 0.50</td>
</tr>
<tr>
<td>Range</td>
<td>9.6, 13.7</td>
</tr>
<tr>
<td>RNFL (µm)</td>
<td></td>
</tr>
<tr>
<td>Mean±SD</td>
<td>81.48 ± 33.36</td>
</tr>
<tr>
<td>Range</td>
<td>15, 212</td>
</tr>
<tr>
<td>MD (dB)</td>
<td></td>
</tr>
<tr>
<td>Mean±SD</td>
<td>-15.23 ± 10.92</td>
</tr>
<tr>
<td>Range</td>
<td>-34.64, -0.06</td>
</tr>
</tbody>
</table>

VA: visual acuity; IOP: intraocular pressure; AL: axial length; WTW: white to white; RNFL: retinal nerve fiber layer; MD: mean defect of visual field.

Distribution of ultrasound cycloplasty probe models
Figure 2 described the distribution of UCP models of these participants. Model 12 are suitable for most of the patients, taking up 69.05% and following by Model 13, which takes up 26.65%. Model 11 account for only 3.35%. NA means all these three models don’t adapt to their eyes, with a percentage of 0.95%.

The Distribution of ultrasound cyclo plasty probe models in nine types of patients

The distribution of ultrasound cyclo plasty probe models in nine types of patients has been shown in Figure 3. It can be seen that Model 12 adapts to most of the patients, including APACG, APACG, MG, SG and high IOP after anti-glaucoma surgery, followed by Model 13, which is consistent with the overall distribution. But for patients with POAG, percentages of Model 12 and Model 13 are similar. Patients with congenital glaucoma are all suitable for Model 13, but there are only 6 cases.

Classification and AL and WTW data of eyes without suitable models

Analyzing the AL and WTW data of 19 eyes without a suitable model, and comparing the AL and WTW data of other eyes with suitable models, the reasons for the lack of a suitable model can be divided into the following three types: short WTW, long WTW and mismatched WTW and AL. We found that an AL that is too short or too long will not result in a calculation without a suitable model, while a WTW that is too short or too long will. When WTW is shorter than 10mm or longer than 13mm, the calculation result is NA. In addition, when WTW is between 10mm and 13mm, if WTW is long and AL is too short, or WTW is short and AL is too long, the calculation result is also NA. Table 2 have shown the AL and WTW data of eyes with no suitable models for three reasons.

<table>
<thead>
<tr>
<th>Type</th>
<th>AL (mm)</th>
<th>WTW (mm)</th>
<th>Type</th>
<th>AL (mm)</th>
<th>WTW (mm)</th>
<th>Type</th>
<th>AL (mm)</th>
<th>WTW (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APACG</td>
<td>24.05</td>
<td>9.6</td>
<td>POAG</td>
<td>25.89</td>
<td>13.0</td>
<td>POAG</td>
<td>28.93</td>
<td>10.6</td>
</tr>
<tr>
<td>APACG</td>
<td>23.22</td>
<td>9.6</td>
<td>POAG</td>
<td>24.52</td>
<td>13.0</td>
<td>APACG</td>
<td>19.11</td>
<td>11.4</td>
</tr>
<tr>
<td>APACG</td>
<td>22.31</td>
<td>9.9</td>
<td>APACG</td>
<td>21.81</td>
<td>13.7</td>
<td>CPACG</td>
<td>20.26</td>
<td>12.3</td>
</tr>
<tr>
<td>CPACG</td>
<td>23.60</td>
<td>9.7</td>
<td>APACG</td>
<td>22.69</td>
<td>13.5</td>
<td>CPACG</td>
<td>26.27</td>
<td>10.1</td>
</tr>
<tr>
<td>SG</td>
<td>23.15</td>
<td>9.8</td>
<td>APACG</td>
<td>22.18</td>
<td>13.4</td>
<td>SG</td>
<td>35.00</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SG</td>
<td>23.86</td>
<td>13.0</td>
<td>SG</td>
<td>19.22</td>
<td>11.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SG</td>
<td>24.95</td>
<td>13.0</td>
<td>SG</td>
<td>19.07</td>
<td>11.8</td>
</tr>
</tbody>
</table>

Discussion
Traditional surgical treatments to destroy the ciliary body, like cyclocryotherapy and cycloodiathermy, deliver the energy in a non-focused form, and that’s why they are non-selectivity and may lead to various adverse reactions. Another method called cyclophotocoagulation delivers focused energy to the eye, but the destroy degree depend on the absorption of the optical energy, which can be influenced by tissue pigmentation[17]. HIFU, unlike optical energy, can be focused to the selected location without being absorbed by the tissues. So the treatment modality ultrasound cyclo plasty using HIFU to cure glaucoma can cause very limited damage to adjacent tissue. With the increasing application of EyeOP1 in clinical, more and more studies have demonstrated this treatment modality has excellent safety and effectiveness in reducing intraocular pressure, and even has some effect in refractory glaucoma patients [8–10, 18, 19]. It means that this technology will probably be used more widely in the future. With the continuous promotion of UCP surgery, it is urgent to conduct research on the UCP probe model distribution to guide clinical decision-making and UCP probe design.

Among the probes suitable for patients who need UCP surgery in China, Model 12 probe accounts for the vast majority, with a proportion of 69.05%, which exceeds the proportion of the other two probe models combined. Model 13 is second, accounting for 26.65%, and Model 11 is far less than the other two with a proportion of only 3.35%. NA means all these three models don’t adapt to their eyes, with a percentage of 0.95%. For patients with POAG and congenital glaucoma, Model 13 accounts for a higher proportion, which is 52.50% and 100%. There are only 4 congenital glaucoma patients with 6 eyes in this study, so the sample size may be not enough to effectively estimate the overall level. Among all eyes using the Model 13 probe, eyes of POAG patients accounted for the highest proportion (45.22%), although PACG patients outnumber POAG patients. Moreover, Model 13 probe accounts for 52.50% among all eyes with POAG, exceeding the other two probes. The probe model is calculated by nomogram with AL and WTW as parameters and the size of the probe model is proportional to AL and WTW. These observations suggest that POAG patients tend to have longer AL, which is consistent with some studies on the axis length of POAG patients. A study conducted by Mieko showed that AL tended to increase as patients with POAG progressed[20]. In contrast, Model 12 probe accounts for the highest proportion among PACG patients. The proportions of Model 12 probe are 81.16%, 77.06% among all probe models in APACG and CPACG patients, respectively. Moreover, among all the eyes using the Model 12 probe, 70.67% of them are eyes of PACG patients. This result indicates that PACG patients tend to have shorter AL. This is consistent with the results of many studies on the axial length of PACG patients[21–23].

In this study, PACG patients, POAG patients and SG patients accounted for 58.00%, 21.08% and 8.12% in all the patients, respectively. According to a systematic review of the prevalence of glaucoma in China, in 2015, the prevalence of POAG, PACG and SG patients in China were 5.22%, 7.14% and 0.76%, respectively[24]. Compared with the statistical results, the consistent conclusion is that the proportion of PACG patients was the highest in this study, followed by POAG patients and SG patients. However, in this study, the proportion of PACG patients was significantly higher than the population. This may be related to the fact that POAG patients choose more medical treatment than surgical treatment, resulting in fewer POAG patients and more PACG patients participating in this study.
Eyes without a suitable model accounted for 0.95% of all eyes, which means that these three types of probes have excellent applicability in Chinese glaucoma patients. Of all the 19 eyes that have no suitable probe model, 26.31% is because of too short WTW (shorter than 10mm), 36.84% is because of too long WTW (longer than 13mm) and 36.84% is because of mismatched AL and WTW. Too long or too short WTW could result that the energy of the probe cannot be effectively focused on the corresponding part of the ciliary body. Even though the length of WTW is within the normal range, when an eye has a long WTW and a too short AL or a short WTW and a long AL, it could result in a difference in the shape of the ciliary body, making the energy focused ineffectively. Therefore, we concluded that the main parameter that mainly affects whether the patient’s eye can have a suitable model is WTW, followed by the consistency of AL and WTW. The mean WTW of the participants in this study is 11.55 ± 0.50mm. It is very close to the result of an investigation on the evaluation of WTW based on a large sample of Chinese cataract patients, in which the mean WTW is 11.69 ± 0.46mm[25]. The verification and analyze of WTW and AL data need to be carried out more in the Chinese glaucoma patient population, though related studies are rare.

As far as we know, this is the first study aimed at the distribution of the probe model of UCP. Despite the sufficient sample size, this study may still be not enough representative of the entire population. This study is a clinical-based cross-sectional study, so the results need to be further documented in community-based epidemiologic survey. But it needs gathering a large number of patients who require surgery and accept ophthalmic testing, which will be a tough challenge.

In conclusion, the present study provides previously unavailable information concerning the patient demographics and distribution of UCP probe model in Chinese glaucoma patients. This study may help surgeons make appropriate decision about UCP probe choices and may assist in the design of new device to execute UCP surgery. Our results need to be confirmed by a larger sample of data in a wider area.

Declarations

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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References


Figures
Figure 1

The distribution of patients and eyes with 7 types of glaucoma

POAG = primary open angle glaucoma; APACG = acute angle-closure glaucoma; CPACG = chronic primary angle-closure glaucoma; MG = mixed glaucoma; SG = secondary glaucoma; CG = congenital glaucoma
Figure 2

Distribution of UCP probe models in Chinese glaucoma patients
Figure 3

Distribution of UCP probe models in 7 types of glaucoma patients

POAG = primary open angle glaucoma; APACG = acute angle-closure glaucoma; CPACG = chronic primary angle-closure glaucoma; MG = mixed glaucoma; SG = secondary glaucoma; CG = congenital glaucoma;