# Tittle Page The ocular biometry characteristics of young patients with primary angle-closure glaucoma

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**Research Article**

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# Abstract

**Backgroud:** Although Primary angle-closure glaucoma (PACG) mainly occurs in elderly people, diagnosis of PACG in young patients is not uncommon . However, there is no article specialized on the ocular anatomical characteristics in these patients.

**Methods:** In this retrospective, comparative study, patients diagnosed with PACG and recieved ultrasound biomicroscopy (UBM) examination in our department were included. Patients were divided into two groups: a young group comprised of patients aged ≤45 years of age and an old group comprised of patients 45 years of age. A-scan ultrasonography and ultrasound biomicroscopy (UBM ) were used to measure ocular biometric parameters of patients in the two groups including axial length (AL), lens thickness (LT), central anterior chamber depth (ACD), anterior chamber width (ACW), angle opening distance 500 (AOD500), anterior angle closure 500 (ACA500), iris thickness 1000 mm from the iris root (IT1000), iris thickness 500 mm from the iris root (IT500), trabecular-ciliary process angle (TCPA), trabecular-ciliary process distance (TCPD), scleral– ciliary process angle (SCPA), lens vault (LV), and pupil diameter (PD). Plateau iris (PI) and base iris insertion were determined from UBM images, and the prevalence of PI and base iris insertion were compared between the two groups. The incidence of postoperative malignant glaucoma (MG) was also determined in both groups and ocular anatomical predictors for the development of malignant glaucoma were evaluated in young PACG patients.

**Results:** 115 patients were included into young group and 144 patients were included into old group. The eyes of patients in the young group had shorter TCPD, shorter AL, narrower TCPA and narrower SCPA compared to the eyes of patients in the old group. There were no significant differences in ACD, LT, AL, LV, AOD 500, ACA500, IT500, IT1000, PD or ACW between the two groups. The prevalence of PI was 25.0% in older patients and 66.1% in younger patients ($P < 0.001$). Significantly more young patients had base iris insertion compared to old patients ($P < 0.001$). 87 patients in young group and 79 patients in old group underwent trabeculectomy in our department. Among these patients, 21 young patients and 4 old patients developed MG after trabeculectomy ($P < 0.001$).

**Conclusions:** AL was shorter, the ciliary body was positioned more anteriorly, prevalence of PI was higher, and incidence of postoperative MG was higher in younger PACG patients compared to older PACG patients. Our results suggest that shorter AL, shorter TCPD and narrower TCPA may be predictors for development of malignant glaucoma in young PACG patients after trabeculectomy.


# Introduction

Primary angle-closure glaucoma (PACG) is a major form of glaucoma in Asia, affecting approximately 0.75% of Asian adults. Although the disease mainly occurs in elderly people, diagnosis of PACG in young patients is not uncommon [1, 2]. However, besides some smaller case reports [3, 4], only one study, conducted by Ritch et al., systematically examined the demographics and clinical appearance of young individuals with angle closure[5]. They investigated angle closure in patients aged 40 years and younger

and found that the etiology of angle closure in young individuals is typically associated with structural developmental ocular anomalies rather than relative pupillary block; however, they did not evaluate ocular anatomical characteristics in these patients.

Eyes with PACG tend to have certain biometric characteristics including a shallow anterior chamber width (ACD), a thick and anteriorly positioned lens, and a short axial length (AL) [6]. Since occlusion of the peripheral anterior angle (AC) is the primary cause of primary angle closure (PAC), the anatomic configurations around the peripheral AC, including the iris root and the ciliary body, also play important roles in the development of PAC [7, 8]. In the present study, the ocular biometric parameters associated with PAC were compared between young and old patients with PACG. Although pupillary block (PB) is considered the most common cause of angle closure, non-pupillary block mechanisms, such as plateau iris (PI), may be responsible for a significant proportion of angle closure, especially in young patients [2, 9–11]. Therefore, the prevalence of PI between young and old patients with PACG was also compared. The main purpose of this study was to evaluate the differences in anatomical characteristics and pathogenesis for angle closure between the young and old PACG patients.

Malignant glaucoma (MG, also known as aqueous misdirection syndrome) is a serious complication, which classically occurs in PACG eyes after trabeculectomy [12, 13]. Young PACG patients are reported to have a higher incidence of malignant glaucoma after trabeculectomy compared to older PACG patients [14–16]. In the present study, the ocular structural characteristics of patients who developed malignant glaucoma after trabeculectomy were also evaluated. In addition, the probability of the occurrence of malignant glaucoma after surgery was determined and the biometric predictors for the development of malignant glaucoma in young patients with PACG were assessed.

# Materials And Methods

### Patients And Data Collection

This was a retrospective, comparative study. We searched our database for patients that were diagnosed with acute or chronic PACG and who received UBM examination in Xiangya Hospital ,Central South University between January 1, 2016 and January 1, 2020. The study was conducted in accordance with the ethical principles specified in the Declaration of Helsinki and was approved by the Xiangya Ethics Committee.

PACG was defined as the presence of appositional angle closure over 270° or more (posterior trabecular meshwork not visible during static gonioscopy in more than three-quarters of the angle circumference, in primary gaze), IOP > 21 mm Hg, and corresponding glaucomatous optic neuropathy. Exclusion criteria were as follows: 1) previous intraocular surgery,including cataract, anti-glaucoma surgery and laser peripheral iridotomy( LPI) ; 2) patients with lens subluxation or intumescent cataract; 3) patients with uveal effusion; 4) patients with retinal detachment; 5) patients with an AL < 19 mm in either eye. Age 45 was chosen as an arbitrary cut off for defining “young” in this study; patients aged ≤ 45 years of age were included in the young group. Patients aged 45 years older who met the criteria were included in the

old group. Because there are too many cases in old group, we selected some of patients for analysis. In order to reduce the bias, the first three patients who received UBM examination in our department every month were included.

The following demographic and clinical data were extracted from the medical record: age, gender, clinical diagnoses, age at diagnosis of PACG, visual field (VF), and parameters measured by A-scan and UBM. A-scan was used to measure AL and lens thickness (LT). UBM examinations were performed in a supine position in a dimly lit room and the UBM parameters were measured as described previously [17]. ACD, pupil diameter (PD), anterior chamber width (ACW) and lens vault (LV) were measured on horizontal perpendicular scans centered over the pupil. ACD was measured from the corneal endothelium to the anterior lens surface, ACW was measured from the nasal scleral spur to the temporal scleral spur and LV was measured from the anterior pole of the crystalline lens to the horizontal line joining the 2 scleral spurs. Anterior chamber angle 500 (ACA500), angle opening distance 500 (AOD500), iris thickness 500 mm from the iris root (IT500), iris thickness 1000 mm from the iris root (IT1000), trabecular-ciliary process distance (TCPD), trabecular-ciliary process angle (TCPA), and scleral– ciliary process angle (SCPA) were measured on the radial scans at the 12-, 3-, 6-, and 9-o'clock positions centered over the limbus. The nasal, temporal, superior, and inferior aspects of these parameters were averaged. ACA500 or the trabecular-iris angle was measured with the apex in the iris recess and the arms of the angle passing through a point on the trabecular meshwork at 500 μm from the scleral spur and the point on the iris perpendicularly opposite. AOD500 refers to the distance between the posterior cornea surface and the anterior iris surface measured on a line perpendicular to the trabecular meshwork 500 μm from the scleral spur; IT500 is the iris thickness at 500 mm from iris root; and IT1000 is the iris thickness 1000 mm from iris root. TCPD was measured as a line extending from a point 500 μm anterior to the scleral spur along the corneal endothelium and dropped perpendicularly through the iris to the most anterior ciliary process seen while scanning in that meridian. TCPA and SCPA were measured between the line tangent to the scleral surface and the axis of the ciliary process. Iris insertion was determined by the location of iris insertion on the ciliary body, and base iris insertion refers to iris insertion that is located at the base of the ciliary body near the scleral spur (Fig. 1). A-scan ultrasound biometry (Model KN-3000A; Quatel Co Ltd., France) and UBM (Model SW-3200L; Tianjin Suowei Electronic Technology Co Ltd., China) examinations and measurements were performed by the same trained physician.

PI was defined based on UBM images using standardized qualitative criteria as described by Kumar et al, that is, anteriorly directed ciliary process, absent ciliary sulcus, steep iris root from the point of insertion followed by a downward angulation, flat iris plane, and irido-angle contact (above the level of the scleral spur) in the same quadrant. At least 2 quadrants had to fulfill these UBM criteria to be defined as having PI [11].

We cobserved the incidence of MG after trabeculectomy surgery in the two groups. Patients who underwent ataract surgery at the same time were excluded. The diagnosis of MG was established based on the following: i) presence of a central and peripheral shallow or flat anterior chamber with a patent iridotomy; and ii) elevated IOP (≥ 21 mmHg). Eyes with suprachoroidal hemorrhage and postoperative

bleb leakage were excluded from this study. To confirm whether patients had postoperative malignant glaucoma, all medical records for each of the patients were checked, and follow-up visits were conducted.

Only one eye per patient was analyzed in this study. If both eyes were eligible for study, data from the the eye with more serious glaucoma was chosen for analysis.

### Statistical Analysis

Statistical analyses were performed using SPSS statistics software 24 (International Business Machines Corporation, USA). The numerical variables are described as mean ± standard deviation (SD) while the categorical variables are described as numbers and percentages.

Differences in mean values between the young and old PACG eyes were examined using the unpaired *t*-test. To determine the possible factors affecting the occurrence of malignant glaucoma in young PACG patients, all the variables measured by A-scan and UBM were assessed using univariate logistic regression analysis and those that were found to be associated ($P < 0.1$) were included in the multivariate logistic regression model. Consequently, insignificant factors were removed using a stepwise approach. $P < 0.05$ was considered statistically significant.

## Results

Between January 1, 2016 and January 1, 2020, 1220 patients were diagnosed with acute or chronic PACG and met our inclusion criteria in our department, of which, 115 patients (9.43%) were younger than 45 years of age and 1105 patients were older than 45 years(90.57%). All the 115 young patients were included into young group and only144 old patients were inlcuded into old group for analysis. The clinical data of young and old PACG patients are shown in Table 1. There were 83 (72.2%) female patients in the young group and 85 (59.0%) female patients in the old group ($P = 0.03$). No significant difference in the visual field MD or PSD was found between the two groups ($P > 0.05$).

Table 1
Comparison of the demographic and clinical characteristics of the young and old PACG patients

| Characteristic | Young group | Old group | *P* |
|---|---|---|---|
| No. of patients | 115 | 144 | |
| Female/male | 83/32 | 85/59 | 0.03 |
| Age | 39.2 ± 6.7 | 69.2 ± 8.8 | < 0.001 |
| MD of VF (dB) | −14.0 ± 6.5 | −12.2 ± 5.5 | 0.52 |
| PSD of VF (dB) | 6.9 ± 4.1 | 5.2 ± 2.5 | 0.54 |

PACG, primary angle-closure glaucoma; MD, mean deviation; LPI, laser peripheral iridotomy; PSD, pattern SD; VF, visual field.

A- scan and UBM parameters in young and old PACG patients are shown in Table 2. The TCPD and AL were significantly shorter and the TCPA and SCPA were significantly narrower in young PACG patients compared to old patients ($P < 0.05$); however, there were no significant differences in ACD, LT, LV, AOD 500, ACA500, IT500, IT1000, PD and ACW between the two groups. The prevalence of PI was 25% in older patients and 66.1% in young patients ($P < 0.001$). Base iris insertion was found in 72 (62.6%) patients in the young group and 31 (21.5%) patients in the old group ($P < 0.001$).

Table 2
Comparison of ocular biometric parameters in young and old PACG patients

| Parameter | Young group | Old group | *P* |
|---|---|---|---|
| AL (mm) | 21.8 ± 1.1 | 22.8 ± 0.8 | < 0.001 |
| LT (mm) | 4.2 ± 0.7 | 4.4 ± 0.6 | 0.23 |
| AOD500 (mm) | 0.02 ± 0.04 | 0.02 ± 0.02 | 0.40 |
| ACA500 (Deg.) | 2.7 ± 4.8 | 2.4 ± 2.8 | 0.87 |
| TCPA (Deg.) | 52.9 ± 11.3 | 60.4 ± 12.4 | 0.01 |
| TCPD (μm) | 0.4 ± 0.08 | 0.5 ± 0.09 | 0.01 |
| SCPA (Deg.) | 61.3 ± 12.3 | 70.7 ± 11.2 | 0.004 |
| LT (μm) | 4.3 ± 0.4 | 4.4 ± 0.5 | 0.21 |
| IT500 (μm) | 0.4 ± 0.06 | 0.4 ± 0.07 | 0.10 |
| IT1000 (μm) | 0.4 ± 0.07 | 0.4 ± 0.06 | 0.45 |
| ACD (μm) | 2.0 ± 0.0 | 1.9 ± 0.2 | 0.16 |
| LV (mm) | 0.8 ± 0.3 | 1.0 ± 0.6 | 0.07 |
| PD | 3.2 ± 0.9 | 3.4 ± 1.0 | 0.30 |
| ACW | 11.5 ± 0.7 | 11.7 ± 0.6 | 0.27 |
| PI (No) | 76 (66.1%) | 36 (25.0%) | < 0.001 |
| BII (No) | 72 (62.6%) | 31 (21.5%) | < 0.001 |
| PMG (No) | 21(24.1%) | 4 (5.1%) | < 0.001 |

ACD, central anterior chamber depth; ACW, anterior chamber width; AL, axial length; AOD500, angle opening distance 500; BII, Basal iris insertion; ICPD, iris-ciliary process distance; IT500, iris thickness at 500 mm from iris root; IT1000, iris thickness at 1000 mm from iris root; LT, lens thickness; LV, lens vault; TCPA, trabecular-ciliary process angle; TCPD, trabecular-ciliary process distance; PI, plateau iris; PMG, postoperative malignant glaucoma.

87 young patients and 79 old patients underwent trabeculectomy in our department. Among these patients, 21 young patients(24.1%) and 4 old patients 5.01%developed MG after trabeculectomy (P < 0.001). Table 3 lists the significant variables that predict the occurrence of MG in young patients with PACG using multivariate regression with the Generalized Estimation Equation. TCPD, TCPA and AL were associated with the occurrence of malignant glaucoma in young patients ($P < 0.05$).

Table 3
Factors predicting the development of PMG in young patients with PACG

| Factor | *β* | *SE* | 95% CI | | Hypothesis Test | | |
|---|---|---|---|---|---|---|---|
| | | | Lower | Upper | Wald Chi-Square | df | P |
| TCPA | −1.12 | 0.54 | 0.11 | 0.88 | 4.80 | 1 | 0.03 |
| TCPD | 168.85 | 74.93 | 3586933959 | 1.28E + 137 | 5.08 | 1 | 0.02 |
| AL | −2.36 | 0.86 | 0.02 | 0.54 | 7.63 | 1 | 0.006 |

AL, axial length; CI, Confidence Interval; PMG, postoperative malignant glaucoma; PACG, chronic primary angle-closure glaucoma; SE, standard error; TCPA, trabecular-ciliary process angle; TCPD, trabecular-ciliary process distance.

# Discussion

In the present study, among 1220 patients with PACG who received trabeculectomy at our department, 115 patients were younger than 45 years old (9.43%). Female in the young PACG patient group was more common than that in the old group (Table 1).

Ocular biometric parameters, including AL, LT, ACD, LV, PD, ACW, TCPA, TCPD, SCPA, LT, IT500, IT1000, AOD500, and ACA 500, were quantitatively compared between young and old PACG patients. To the best of our knowledge, this is the first study detailing the ocular biometric characteristics of young patients with PACG. Among the ocular biometric parameters examined in this study, TCPD and AL were shorter and SCPA and TCPA were narrower in young PACG patients compared to old PACG patients (Table 2).

TCPD, TCPA and SCPA are important parameters that reflect the anterior position of the ciliary process [11, 18, 19]. Narrower SCPA and TCPA and shorter TCPD indicate a more anterior position of ciliary processes. A shorter TCPD has been found in PAC/PACS eyes compared to eyes with non-occludable angles and is associated with an increased risk of progressive angle-closure in the fellow eyes of acute PAC patients [18, 19]. The anterior rotation of ciliary process can push the iris root forward, resulting in a narrowing of the angle, which could be a predisposing factor for the development of creeping angle closure. In our study, SCPA and TCPA were narrower and TCPD was shorter in young PACG patients than old PACG patients, indicating a more anterior position of the ciliary processes in the young PACG patients than in the old PACG patients.

Several previous studies have suggested that the iris plays an important role in the pathogenesis of angle closure [8, 20, 21]. A thicker peripheral iris and a more basal iris insertion are associated with an increased risk of angle closure. In our study, peripheral iris thickness was similar between the old and young PACG patients, but basal iris insertion was more common in young patients than in old patients.

In PI, large and anteriorly inserted ciliary processes hold the iris root in apposition to the trabecular meshwork, resulting in spontaneous or provoked acute or intermittent angle closure. Previous studies have shown that the prevalence of PI in primary angle-closure suspect (PACS) eyes is 32.3% [10], while the prevalence of PI in PACG patients from Singapore after LPI using standardized UBM criteria is about 30% [12]. These findings highlight the importance of non-pupil block mechanisms related to angle closure in Asian individuals. Ritch et al. [5] systematically examined the demographics and clinical appearance of young individuals with angle closure and found that PI was the most common diagnosis (52.2%) in a relatively inhomogeneous sample of 67 patients with angle closure symptoms. In our study, using the predefined UBM criteria, we found that the prevalence of PI was 66.1% in young patients with PACG, which was significantly higher than that in old patients. The prevalence of PI in young PACG patients was similar to that reported in the study by Ritch et al[5], but was much higher than those in elderly patients reported by other studies. Our results indicate that young patients with PACG are most likely to have PI and the mechanisms causing angle closure in young patients differ from those in older patients.

The thicker and more anteriorly located lens, as well as a shorter AL, are thought to be predisposing factors for angle-closure [22–25]. Sihota et al suggested that the occurrence of angle-closure was largely related to a shorter AL and a thicker lens, resulting in a shallower ACD. In our study, we found that the AL was significantly shorter in young PACG patients than that in old patients; however, there was no difference in LT or LV between young and old PACG patients, although LT and LV are reported to increase with age.

MG is typically known to occur after glaucoma filtration surgery in eyes with PACG and the incidence of MG has been reported to be approximately 0.6–4% [12]. Young age is an important risk factor for the development of MG. In our study, the incidence of postoperative MG was 24.1% in young patients with PACG (Table 3), which was much higher than that in old patients, and higher than those reported in previous studies[12]. Short AL, shallow anterior chamber, large lens, more anteriorly rotated ciliary bodies and PI are considered as anatomic risk factors for the development of MG[14–16, 26]. In our study, the AL was shorter, the ciliary body was positioned more anteriorly, prevalence of PI was higher in younger PACG patients compared to older PACG patients. Our findings suggest that these ocular biometry characteristics may be the reason that young patients with PACG were more likely to develop MG after trabeculectomy. In our study, we found that shorter AL and more anteriorly rotated ciliary bodies might be predictors for the development of MG in young patients with PACG .

Our study was limited by its retrospective design, which may have affected the selection of patients. Another limitation of this study was that the gonioscopic and quantitative measurements of UBM images were performed by the same examiner, which could cause observational bias.

In conclusion, compared to old patients with PACG, young patients with PACG had shorter ALs, more anterior position of ciliary processes, more cases of basal iris insertion, higher prevalence of PI and higher incidence of MG. The origin of these anatomic abnormalities is congenital rather than acquired as PB, and it could be the reason that young patients develop angle closure at much earlier age and develop MG after trabeculectomy. Although AOD500 and ACA500 were similar between the young and old PACG patients, we speculate that the mechanisms related to the narrowing of the angle in the two groups are different. In contrast to old PACG patients, non-pupil block mechanisms are the main cause of angle closure in young patients with PACG, thus iridectomy may not be an effective treatment for angle closure in these patients [27]. Therefore, in young patients with glaucoma, gonioscopy and UBM should be used to examine the angle structure, to determine the pathogenesis of glaucoma and provide the correct treatment.

# Declarations

CONFLICT OF INTEREST

The authors declare that there is no competing interest.

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AVAILABILITY OF DATA AND MATERIALS

The datasets used during the current study are available from the corresponding author on reasonable request.

AUTHORS' CONTRIBUTIONS

Research design: Dan Liu ,Qian Tan; UBM and A-scan examination : Yi Xu ; acquisition of data: Yi Xu ; data analysis and manuscript writing: Dan Liu,Chunyan Li . All the authors have read and approved of the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was conducted in compliance with informed consent regulations and the Declaration of Helsinki. Oral informed consent was obtained from all the participants and the oral informed consent procedure was approved by Xiangya Hospital Ethics committee. The study protocol was approved by Xiangya Hospital Ethics Committee.

CONSENT FOR PUBLICATION

Not applicable.

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# Figures

**Figure 1**

UBM image of a quadrant depicting basal iris insertion