Objective: To determine the prevalence of plateau iris in Asian eyes with primary angle closure glaucoma (PACG) using ultrasound biomicroscopy (UBM).

Methods: In this cross-sectional observational study, subjects older than 40 years with PACG who had a patent laser peripheral iridotomy underwent UBM in 1 eye. Ultrasound biomicroscopy images were qualitatively analyzed using standardized criteria. Plateau iris in a quadrant was defined by anteriorly directed ciliary body, absent ciliary sulcus, steep iris root from its point of insertion followed by a downward angulation, flat iris plane, and irido-angle contact. At least 2 quadrants had to fulfill these UBM criteria for an eye to be classified as having plateau iris.

Results: One hundred eleven subjects (70 from Singapore, 41 from Thailand) with PACG were recruited. The mean (SD) age was 65.6 (8.1) years, and 63.9% were female. Based on standardized UBM criteria, plateau iris was found in 36 of 111 eyes (32.4%; 95% confidence interval, 24.4%-41.6%). In these 36 eyes, quadrant-wise analysis showed 66.7% had plateau iris in 2 quadrants; 22.2%, in 3 quadrants; and 11.1%, in all quadrants.

Conclusions: About 30% of PACG eyes with a patent laser peripheral iridotomy were found to have plateau iris on UBM, highlighting the importance of non–pupil block mechanisms in Asian individuals.


Primary angle closure glaucoma (PACG) is a major form of glaucoma in Asia.1 In China, PACG accounts for 91% of bilateral glaucoma blindness.2 Laser peripheral iridotomy (LPI) is the accepted first-line treatment in the management of eyes with PACG; however, it has been shown that LPI alone does not prevent a rise in intraocular pressure (IOP) and/or progression of disease in all instances.3,4 This might be because LPI only relieves pupil block; recent evidence has shown that non–pupil block mechanisms, such as plateau iris, may play a far more important role in the PACG disease process than previously thought.5-8

Plateau iris has been traditionally defined as an occludable angle on gonioscopy, with a flat iris plane and a relatively deeper central anterior chamber.9 In eyes with plateau iris, a large ciliary body and/or anteriorly directed ciliary processes have been shown to hold the peripheral iris in apposition to the trabecular meshwork in the presence of a patent LPI.10 The advent of ultrasound biomicroscopy (UBM) as an imaging tool has helped to increase the understanding of underlying mechanisms for PACG, such as plateau iris, because it can visualize structures posterior to the iris, like the ciliary body, that are otherwise not visible by clinical examination methods like gonioscopy.

In eyes with plateau iris, irido-angle contact may persist after LPI, and this can potentially be one of the causes for progression of the angle closure disease process. Two recent reports have investigated the role of non–pupil block mechanisms such as plateau iris in primary angle closure suspects (PACS) in Singapore and China.11,12 About 30% (54 of 167) of PACS eyes from Singapore were found to have plateau iris using standardized UBM criteria in the presence of a patent LPI.11 The Liwan Eye Study reported that 60% of PACS eyes had a plateau iris configuration with persistent appositional closure in at least 1 quadrant in the presence of a patent LPI.

The aim of this study was to determine the prevalence of plateau iris in Asian subjects with PACG using qualitative and standardized UBM criteria. We used identical study methods and UBM criteria for the diagnosis of plateau iris used in our
METHODS

This was a prospective, observational study of consecutive subjects older than 40 years who were previously diagnosed with PACG and were being followed up in the glaucoma clinics at the Singapore National Eye Centre, Singapore, and King Chulalongkorn Memorial Hospital, Bangkok, Thailand. All subjects had previously undergone LPI. Written informed consent was obtained from all subjects, and the study protocol was approved by the hospitals’ ethics committee and was performed according to the tenets of the Declaration of Helsinki.

All subjects underwent a complete ophthalmic examination including visual acuity testing, IOP measurement with Goldmann applanation tonometry, visual field testing (Humphrey Visual Field Analyzer II, Carl Zeiss Meditec, Dublin, California, using the standard Swedish interactive threshold algorithm with a 24-2 test pattern), axial length and central anterior chamber depth measurement, and optic disc examination. Dynamic (indentation) gonioscopy was performed using a Sussman 4-mirror gonioscope (Sussman Medical Instruments, Salt Lake City, Utah, and Suowei Electronic Technology, Tianjin, China). A single observer performed both the UBM scanning and grading for quadrants by a single glaucoma fellowship–trained observer based in Singapore (R.S.K.), masked to clinical data. The same observer performed both the UBM scanning and grading for the Singapore cohort and the grading for the UBM images from Thailand.

Plateau iris was defined in a quadrant if all the following criteria were fulfilled (Figure):

1. The ciliary process was anteriorly directed, supporting the peripheral iris so that it was parallel to the trabecular meshwork.
2. The iris root had a steep rise from its point of insertion, followed by a downward angulation from the corneoscleral wall.
3. Presence of a central flat iris plane.
4. An absent ciliary sulcus.
5. Irido-angle contact (above the level of the scleral spur) in the same quadrant.

An eye was defined to have plateau iris if at least 2 quadrants fulfilled all these criteria. To assess intraobserver reproducibility, 70 eyes (280 quadrants) were randomly selected and regraded for plateau iris by the same observer on a separate day using the same UBM criteria; intraobserver reproducibility was assessed with χ statistics. Statistical analysis was performed using Medcalc software (Mariakerke, Belgium). Parametric and nonparametric tests were used to compare continuous variables, according to data distribution. The χ² test was used to compare categorical data.

RESULTS

A total of 111 subjects with PACG were enrolled, 70 from Singapore and 41 from Thailand. Subjects were Chinese (59.5%), Thai (36.9%), or of other Asian races (3.6%). The mean (SD) age was 65.6 (8.1) years (range, 44-90 years), and 63.9% were female. The mean axial length was 22.95 mm (95% confidence interval [CI], 22.75-23.16 mm), mean anterior chamber depth was 2.37 mm (95% CI, 2.29-2.44 mm), and mean vertical cup-disc ratio was 0.75 (95% CI, 0.71-0.78). All eyes had a patent LPI. There were no patients who had previously undergone laser iridoplasty. Gonioscopy showed that 51 of 111 patients (45.9%) had persistent irido-angle contact in the presence of a patent LPI. We had data on the extent of PAS in 70 eyes; 35 of 70 eyes (50%) had PAS. Of these, 16 eyes had PAS in 1 clock hour and 15 eyes, in 2 clock hours; 3 eyes had 180° PAS; and 1 eye had 360° PAS.

Ultrasound biomicroscopy images were available for all eyes (except for 1 quadrant each in 2 eyes that had images of poor quality and were not assessed). Based on standardized UBM criteria, plateau iris was diagnosed in 36 of 111 PACG eyes (32.4%; 95% CI, 24.4%-41.6%) (Figure); this included 23 of 70 eyes (32.8%) from Singapore and 13 of 41 eyes (31.7%) from Thailand.
On quadrant-wise analysis, 24 of 36 eyes (66.7%) were found to have plateau iris in 2 quadrants, 8 of 36 (22.2%) in 3 quadrants, and 4 of 36 (11.1%) in all 4 quadrants. In 55 of 111 eyes (49.5%), plateau iris was not found in any quadrant. Plateau iris was found in the superior quadrant in 34 eyes, inferior quadrant in 32 eyes, nasal quadrant in 20 eyes, and temporal quadrant in 21 eyes.

Twenty-seven of 111 eyes (24.3%) fulfilled all the criteria for plateau iris on UBM except that there was no irido-angle contact in any of the quadrants. Twenty-five of the 111 eyes (22.5%) had persistent irido-angle contact on UBM but did not fulfill the criteria for plateau iris. Quadrant-wise analysis of these eyes showed that 12 of 25 eyes (48%) had persistent contact without plateau iris in 2 quadrants, 4 of 25 (16%) in 3 quadrants, and 9 of 25 (36%) in all 4 quadrants.

We determined intraobserver reproducibility for diagnosing plateau iris in a sample of 70 eyes (280 angles) and found that this was moderate ($\kappa=0.77$).

**COMMENT**

In this observational study using standardized UBM criteria, we found plateau iris in about a third of Asian PACG eyes with a patent LPI. This prevalence was similar in Singaporean (32.8%) and Thai (31.7%) subjects and was comparable with our previous report on the prevalence of plateau iris in PACS (32.3%) from Singapore. Recent published reports concur that plateau iris is quite common in PACG; this has been reported in Chinese people as well as young white individuals with PACG. A study from China estimated that pure pupillary block only accounts for 38% of angle closure in Chinese individuals and 54% had combined mechanisms, while a recent review suggested that non–pupil block mechanisms may be responsible for a significant proportion of angle closure in Asian individuals. A UBM study from India reported persistence of narrow angles after LPI in 60% of PACG eyes, and using UBM, the authors found an anteriorly positioned ciliary process with a narrow ciliary sulcus in 67% of such eyes. The high prevalence of plateau iris in Asian eyes may in part help to explain the high rate of chronic angle closure and raised IOP occurring in PACG eyes in the presence of a patent LPI.

About 25% of eyes satisfied all the requirements for classification of plateau iris but had open angles on UBM. In our published data on the prevalence of plateau iris in PACS, we had reported that 23.4% of PACS eyes had similar UBM findings after LPI. Earlier studies have also reported similar findings. Interestingly, none of the patients in this study were previously diagnosed with plateau iris because it was not detected clinically and UBM is not performed routinely for all cases of PACG in the 2 centers. Patients in our study were using a variety of IOP-lowering medications, including $\beta$-blockers, prostaglandin analogues, $\alpha$-agonists, and pilocarpine. None of the subjects had undergone iridoplasty after LPI. The optimum management of plateau iris is not established because of a lack of randomized controlled trials of treatment. It is not even established if all cases of plateau iris warrant further treatment to prevent IOP increase and/or progression of angle closure disease. One recent study reported the long-term effectiveness of laser iridoplasty for a small cohort of subjects diagnosed with plateau iris by gonioscopy. Others have described the use of pilocarpine for this condition. While prostaglandin analogues have been found to be effective in lowering IOP in eyes with PACG, their efficacy in plateau iris has not been investigated. There is a need for more prospective studies on the optimum treatment of plateau iris, whether medical, laser, or by surgery.

In addition to developing treatment strategies for plateau iris, there is a need to establish the diagnostic criteria for this condition. The Liwan Eye Study defined the plateau iris profile gonioscopically as the iris rising steeply from its insertion but making an abrupt angulation away from the corneoscleral wall, resulting in a relatively deep central anterior chamber and a centrally flat iris plane. The number of quadrants that were required to demonstrate this profile was not specified. We believe that the diagnosis of plateau iris using gonioscopy is subjective and may have lower reproducibility compared with diagnosis based on UBM images of the angle. However, there is also no consensus on UBM diagnostic criteria for plateau iris. Garudadri et al. defined plateau iris on UBM as an angle where anteriorly directed ciliary processes in approximation with the peripheral iris obliterate the ciliary sulcus but did not specify the number of quadrants required for diagnosis. We have tried to define plateau iris using standardized UBM criteria because we believe that it is important to establish definitive and possibly quantitative criteria that are reproducible. Our UBM definition was relatively strict because all 5 criteria had to be present in at least 2 quadrants. If we were to use a less strict definition (eg, 1 quadrant only), the prevalence of plateau iris would have been even higher. Although the UBM criteria seem more objective, we acknowledge that UBM findings may also be variable and may be affected by imaging technique, UBM operator, or lighting conditions. Some subjectivity may also be involved when interpreting the UBM images. For example, one needs to consider the degree of angulation of the ciliary body, the extent of contact between the ciliary body and iris, and the length of the ciliary sulcus. The interobserver reproducibility may also vary; we have only assessed intraobserver variability and this was shown to be moderate in this study and in our previous report.

Our study has a few limitations. Subjects with PACG were recruited from 2 centers from 2 different countries, and because there were different UBM operators, this may have reduced the standardization of imaging. The clinical examination was also not standardized and we did not have complete clinical information for all subjects in the study, such as previous medical therapy. For the Singapore arm of the study, both the UBM scans and grading of the images thereafter were performed by the same observer (R.S.K.); this might have caused bias. The analysis of the angle in each quadrant by UBM was based on only a cross-sectional image of the angle and there may be variations in the quadrant that may be missed by this image. For example, if the UBM scan was over an area of PAS, this will show angle closure but this may not be representative of the remaining areas of the angle (which may be open). Unfortunately, we did not have
data on which quadrants had PAS and had plateau iris diagnosed in the same quadrant. Finally, there were some patients with PACG who were being treated with pilocarpine and this may have altered angle morphology and/or affected the diagnosis of plateau iris.

In conclusion, about a third of subjects with PACG from Singapore and Thailand were diagnosed with plateau iris based on standardized UBM criteria in the presence of a patent LPI. These findings are similar to our previous report on the prevalence of plateau iris in PACS eyes and highlight the significance of non–pupil block mechanisms for angle closure disease in Asian individuals. However, clinicians may need to consider this factor when managing Asian patients with PACG as it is likely that responses to therapies will vary according to the mechanism involved.

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