Ultrasound Biomicroscopy Measured Anterior and Posterior Chamber Diameters-A Novel Way to Evaluate Angle-Closure Glaucoma

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Objective: *To investigate anterior and posterior chamber diameters in primary angle-closure (PAC) and to correlate them to the angle opening parameters.*
Material and Method: *Fifty eyes of PAC and 45 age-matched controls underwent ultrasound biomicroscopy (UBM; model P60, Paradigm Medical Industries Inc., Salt Lake City, UT) scanning. Superior, inferior, temporal and nasal angle opening parameters were obtained. Anterior chamber diameter, indicated by angle-to-angle diameter (AAD) and posterior chamber diameter, indicated by sulcus-to-sulcus diameter (SSD), were analyzed.*
Results: *Mean age was not different between PAC and controls, 59.80 $\pm$ 9.11 versus 56.33 $\pm$ 13.39, respectively ($p = 0.140$). PAC demonstrated a relatively smaller eye than the controls; e.g., corneal diameter, anterior chamber depth (ACD) and axial length, (all $p < 0.05$). AAD was shorter in PAC than the controls, 10.16 $\pm$ 0.58 versus 10.88 $\pm$ 0.55 mm, ($p < 0.001$). AAD was correlated to PAS extent ($r = -0.358$), ACD ($r = 0.659$), SSD ($r = 0.636$) and scleral spur to iris root insertion ($r = 0.505$), (all $p < 0.001$). SSD was also smaller in PAC than controls, 10.16 $\pm$ 0.45 versus 10.52 $\pm$ 0.52 mm, ($p = 0.001$).*
Conclusion: *Crowded anterior segment of PAC can be demonstrated by a novel parameter of AAD and SSD, obtained with a newer model of UBM. The shorter AAD indicates the greater PAS extent and smaller angle. Both parameters are independent to scleral spur, and are simple to evaluate PAC.*

Keywords: *Angle-closure glaucoma, Ultrasound biomicroscopy, Anterior chamber diameter, Posterior chamber diameter, Peripheral anterior synechia, Asian*

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Primary angle-closure glaucoma (PACG) is a leading cause of blindness worldwide. Asians have a higher prevalence than Caucasians[1-3]. Anatomical disorder of a relatively small eye induces iris apposition to trabecular meshwork[4]. Pupillary block is the common mechanism of angle closure. Gonioscopy is an essential tool to detect angle closure. Indentation gonioscopy can differentiate occludable angle from peripheral anterior synechia (PAS)[5]. Progressive obliteration of trabecular meshwork by peripheral iris is shown as shortening of iris root insertion (creeping angle)[6]. However, gonioscopy is a semi-quantitative technique, and a relatively subjective method to measure the angle.

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Ultrasound biomicroscopy (UBM), using a high frequency of 50 MHz ultrasonography, demonstrates anterior segment structures and determines many anterior segment parameters[7]. It is a useful device for primary angle-closure (PAC) evaluation. In such patients, UBM indicates iris convexity, relatively small anterior chamber depth (ACD), angle opening distance (AOD), trabecular-ciliary process distance (TCPD)[8], scleral spur to iris root insertion (SS-IR), angle recession area[9], thinner ciliary body[10] and more frequent uveal effusion[11]. Iris thickness is variable among subtypes of PAC[12]. Laser peripheral iridotomy (LPI) flattens the iris convexity by equalizing posterior chamber pressure to anterior chamber pressure, and opens the angle. Argon laser peripheral iridoplasty (ALPI) makes the peripheral iris thin, and opens the appositional angle in plateau iris syndrome[13]. However, ALPI does not change the ciliary processes position.

By using a newer UBM model, a single view of scanning demonstrates anterior chamber diameter indicated by angle-to-angle diameter (AAD) and posterior chamber diameter or ciliary sulcus diameter, indicated by sulcus-to-sulcus diameter (SSD) images, can be detected. Because these parameters do not mark scleral spur for measurement, they may be useful for evaluation in PAC. These two parameters have never been studied in PAC. The authors evaluated whether or not they correlate to PAS extent and other parameters.

Material and Method

Study design was a comparison of new parameters between PAC and healthy controls. The protocol was approved by the Institutional Review Board of Rajavithi Hospital. Informed consent was read and signed by all participants. PAC patients, including PAC suspect (PACS), PAC and PACG, were invited to be in the study group. PACS was defined as a patient who had occludable angle (Shaffer's gonioscopic grade 2 or less, in at least three quadrants). PAC was defined as PACS with PAS and/or IOP was higher than 21 mmHg. PACG was PAC with glaucomatous optic disc and visual field damage. Peripherals anterior synechia were defined as the peripheral iris adhering to the trabecular meshwork, which could not be opened with indentation gonioscopy. The extent was recorded in degrees. Patient who underwent LPI was eligible. Pilocarpine was discontinued at least seven days prior to ocular and UBM evaluation.

Exclusion criteria included nanophthalmos, as well as patients who had a history of ALPI, or intraocular surgery, *e.g.*, cataract extraction, or trabeculectomy.

The control group was age-matched with healthy subjects of Rajavithi Hospital staff and patients who were scheduled for cataract surgery, but who otherwise had a normal ocular condition.

Ocular examination was performed, including auto-refraction, slit-lamp examination, Goldmann applanation tonometry, indirect gonioscopy (Zeiss-4-mirror) with and without indentation, and optic disc evaluation. White-to-white horizontal and vertical corneal diameters were measured with calipers, with accuracy to 0.5 mm. A-scan ultrasonography (Ocuscan, Alcon, Fort Worth, TX) was performed to measure the axial length. UBM (model P60, Paradigm Medical Industries Inc., Salt Lake City, UT) was performed in supine position and in a standard room lighting condition, under an immersion technique by a glaucoma fellow skilled in UBM (KY). When scanning the study eye, the authors asked the subjects to fix the contralateral eye on the fixation target of the room ceiling to prevent accommodation. Peripheral angles were scanned for the four quadrants of superior (90°), nasal (0°), inferior (270°) and temporal (180°). A single view of angle-to-angle was scanned through the center of the cornea. In addition, the operator adjusted the UBM transducer to view the anterior segment in vertical (90°-270°) and horizontal (0°-180°) axes. Image quality must be clear to view anterior segment structures, including ciliary sulci (Fig. 1). UBM parameters of ACD, AAD, SSD, AOD at 500 μm (AOD 500) and SS-IR, were measured by one of the researchers (CK) masked to the patient diagnosis.

AAD was defined as the distance between the iris root insertions of that axis. If the iris root insertion could not be identified because of angle-closure, the most anterior part of peripheral iris touching to the angle would be applied for measurement. SSD was defined as the distance between the ciliary sulcus. If the sulcus was closed by the anterior position of cilary process, the most inner part of the sulcus would be applied for measurement (Fig. 1).

Data set of the right eye was recorded and analyzed with SPSS for Windows, version 11.5 (SPSS Inc., Chicago). Student t-test and Chi-square were tested for the variables. Spearman's correlation analysis was tested for the relationship between the variables. Significant difference was set at $p < 0.05$.

Results

Fifty patients participated in the study group and 45 in the control group. The right eye data set was

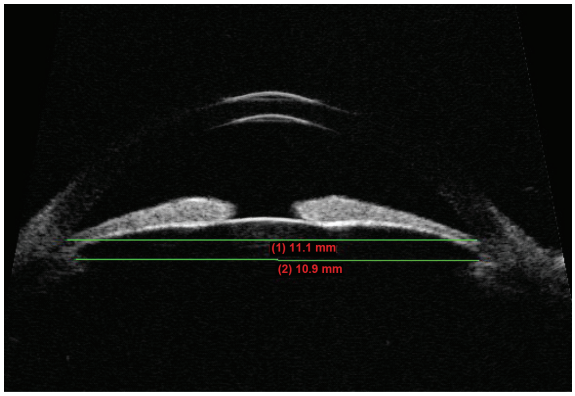

Fig 1. Measurement of angle-to-angle diameter (line 1), and sulcus-to-sulcus diameter (line 2) with ultrasound biomicroscopy by a single view image

Table 1. Demographic and clinical data

Data	PAC (n = 50)	Controls (n = 45)	p-value
Age (years)	59.80 ± 9.10	56.30 ± 13.40	0.14
Sex: female, n (%)	45 (90%)	35 (77.8%)	0.103
Spherical equivalent	0.43 ± 1.80	-0.69 ± 1.37	0.001
Keratometry	44.63 ± 1.29	43.95 ± 1.48	0.019
Corneal diameter (mm):			
Horizontal	11.41 ± 0.79	11.77 ± 0.98	0.05
Vertical	10.79 ± 0.65	11.24 ± 0.82	0.005
Corneal diameter average	10.87 ± 1.73	11.51 ± 0.88	0.031
Shaffer's gonioscopic grading	0.62 ± 0.86	3.69 ± 0.46	<0.001
PAS extent (degree)	78.10 ± 141.9	0	<0.001
IOP (mmHg)	29.00 ± 15.10	13.60 ± 3.50	<0.001
Cup disc ratio	0.58 ± 0.23	0.35 ± 0.12	<0.001
Axial length (mm)	22.31 ± 0.79	23.23 ± 0.99	<0.001

IOP = intraocular pressure; PAS = peripheral anterior synechia; PAC = primary angle-closure

analyzed. PACS was diagnosed in nine eyes (18%), PAC in six eyes (12%) and PACG in 35 eyes (70%). Of the PACG, 16 eyes (45.7%) had a history of acute attacks and 19 eyes (54.3%) were chronic PACG. Within the study group, 27 eyes (54%) were newly diagnosed, they underwent LPI after UBM was scanned. In addition, 23 eyes (46%) had already undergone LPI before UBM scanned.

Mean age and sex were not different between the groups. The study group was more hyperopic than the control group. PAS was detected by gonioscopy in 14 eyes (28%) of the study group. Mean PAS extents were 78.1 ± 141.9 degrees. Comparative parameters between groups are shown in Table 1.

Ultrasound biomicroscopy parameters of ACD, AOD 500, SS-IR, AAD, and SSD averages in PAC were smaller than controls, $p < 0.05$ (Table 2). ACD-to-AAD ratio was smaller in PAC than the controls. AAD was significantly correlated to corneal diameter, PAS extents, ACD, AOD 500, SS-IR, and SSD, all $p < 0.05$ (Table 3).

AAD average in female was shorter than male, 10.41 ± 0.66 vs. 10.94 ± 0.52 mm ($p = 0.004$). Furthermore, SSD average was shorter too, 10.25 ± 0.49 vs. 10.75 ± 0.44 mm ($p < 0.001$).

Table 2. Ultrasound biomicroscopy parameters between primary angle-closure and control eyes

Parameters	PAC (n = 50)	Controls (n = 45)	p-value
ACD (mm)	1.91 ± 0.32	2.62 ± 0.37	<0.001
AOD 500 (mm)			
Superior	0.10 ± 0.12	0.40 ± 0.16	<0.001
Nasal	0.09 ± 0.13	0.39 ± 0.21	<0.001
Inferior	0.12 ± 0.13	0.39 ± 0.17	<0.001
Temporal	0.11 ± 0.11	0.39 ± 0.20	<0.001
AOD 500 average	0.10 ± 0.10	0.39 ± 0.15	<0.001
SS-IR (mm)			
Superior	0.04 ± 0.11	0.30 ± 0.20	<0.001
Nasal	0.06 ± 0.11	0.28 ± 0.21	<0.001
Inferior	0.04 ± 0.08	0.33 ± 0.30	<0.001
Temporal	0.08 ± 0.13	0.26 ± 0.26	<0.001
SS-IR average	0.05 ± 0.08	0.29 ± 0.18	<0.001
AAD (mm)			
Horizontal	10.13 ± 0.63	10.91 ± 0.56	<0.001
Vertical	10.18 ± 0.63	10.84 ± 0.60	<0.001
AAD average	10.16 ± 0.58	10.88 ± 0.55	<0.001
SSD (mm)			
Horizontal	10.07 ± 0.51	10.44 ± 0.59	0.002
Vertical	10.25 ± 0.48	10.60 ± 0.57	0.002
SSD average	10.16 ± 0.45	10.52 ± 0.52	0.001
ACD-to-AAD ratio	0.19 ± 0.03	0.24 ± 0.03	<0.001

AAD = angle-to-angle diameter; ACD = anterior chamber depth; AOD 500 = angle opening distance at 500 μm; PAC = primary angle-closure; SSD = sulcus-to-sulcus diameter; SS-IR = scleral spur to iris root insertion

Discussion

AAD indicated the anterior position of peripheral iris. It had a relationship to angle opening parameters. Even though it was well expected to be smaller in PAC than normal subjects, it was not evaluated previously. A relatively small angle,

Table 3. Correlation between various ocular parameters and the AAD average

	Spearman's correlation coefficient, r	p-value
Corneal diameter	0.314	0.002
PAS extent	-0.358	<0.001
ACD	0.659	<0.001
AOD 500 average	0.624	<0.001
SS-IR average	0.505	<0.001
SSD average	0.636	<0.001

AAD = angle-to-angle diameter; ACD = anterior chamber depth; AOD 500 = angle opening distance at 500 μm; PAS = peripheral anterior synechia; SSD = sulcus-to-sulcus diameter; SS-IR = scleral spur to iris root insertion

determined by PAS extents, anterior iris insertion (shorter SS-IR) and shorter AOD 500, correlates to smaller AAD. Their correlations are promising for PAC evaluation. This is because AAD is independent from the scleral spur. Scleral spur is an important landmark for angle measurements, *e.g.*, AOD 500, TCPD and SS-IR[8]. It is difficult to detect in PAC who has appositional angle or who has PAS. The ultrasonic reflectivity of anterior iris surface and scleral spur are similar. When they are apposed together, identification of the scleral spur is not applicable. Shortening of AAD indicated crowded anterior chamber, because ACD is always used to study PAC. However, ACD indicates the central dimension of the eye, not the peripheral. AAD was closely related to the angle dimension, which is important for PAC evaluation. The authors coined a parameter of ACD-to-AAD ratio and found that it was smaller in PAC than in the controls.

AAD was negatively correlated to PAS extent. The correlation was weak, but significant. One possible reason for the weak correlation was the area of measurement of the parameters. AAD measurement was made in only the vertical and horizontal manners, while PAS extent was a circumferential measurement. AOD 500 applied at the same manners of measurement as AAD (vertical and horizontal). AAD and AOD 500 might not indicate PAS. PAS was detected by indentation gonioscopy, but AAD and AOD 500 were performed without indentation. The present study revealed that AAD was correlated to SS-IR. Shortening of iris root insertion indicates creeping angle in gonioscopic examination. As the authors mentioned above, gonioscopy is relatively subjective. On the other hand, UBM parameters are objective and reproducible[14]. It may be a useful parameter for follow-up of angle-closure progression. Choi et al[15] reported PAS progression in one-third of PAC by gonioscopy records. A cohort study is needed to validate AAD application in PAS progression.

Posterior chamber diameter in PAC was also smaller than in the controls. Anterior position of ciliary process, determined with TCPD, is commonly found in PAC[12,16,17]. The anterior position of the ciliary processes push the peripheral iris forward, leading to shortening AAD. Quigley proposed that choroidal expansion is one of the possible mechanisms of PAC[18]. Uveal effusion may indicate choroidal expansion[11]. Sakai et al[11] reported the prevalence of uveal effusion in chronic PAC as 14% and in acute PAC as 58%. However, the authors did not find any uveal effusion in any subject. The possible reason was due to the scanning area. The authors scanned only four angles, not circumferentially as in Sakai's method.

Posterior chamber appears to be vertically oval shape[19,20]. The present study also emphasizes this finding. In healthy control subjects, the SSD obtained with 50-MHz UBM in the present study was smaller than 35-MHz UBM, which was reported by Oh et al[20] in their Korean subjects. Horizontal SSD was 10.44 ± 0.59 versus 10.07 ± 0.40 mm and vertical SSD was 10.60 ± 0.57 versus 11.99 ± 0.36 mm, respectively. However, the mean age of the present study was almost three decades older than that in Oh's study, 56.3 versus 28.4 years. Blum et al[19] reported the age-related decrease in posterior chamber diameter in 64 human autopsy eyes. The shortening of posterior chamber diameter by aging and its role in patho-physiology of PAC remain to be elucidated.

Limitations of the present study included the relatively small sample size. The authors did not analyze the UBM parameters in subgroups of patients. Females were predominated in number of cases. In addition, AAD could be affected by variation of iris surface contour. In the eye with relative pupillary block, the convexity of the peripheral iris might be relieved with intensity of room lighting[21]. Accommodation and LPI could change the iris contour. These factors could alter the peripheral iris position and AAD.

In conclusion, crowded anterior segment of PAC can be determined with the novel parameters of AAD and SSD. The parameters are independent from the scleral spur, and are correlated with PAS extent. These simple parameters appear to be useful in PAC evaluation.

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Potential conflicts of interest

None.

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การศึกษาระยะของช่องตาส่วนหน้าและส่วนหลังวิธีใหม่โดยใช้ ultrasound biomicroscopy ในผู้ป่วยต้อหินแบบมุมตาปิด

ชนิยา กุลชาญพิเศษ, กนกวรรณ ยุตติธรรม, บุญส่ง วนิชเวชารุ่งเรือง

วัตถุประสงค์: *เป็นการประเมินระยะของช่องตาส่วนหน้าและส่วนหลังวิธีใหม่ ในผู้ป่วยต้อหินแบบมุมปิดโดยใช้ ultrasound biomicroscopy (UBM) และนำไปแสดงความสัมพันธ์กับการวัดมุมตาด้วยวิธีที่เคยใช้กันมาก่อน*

วัสดุและวิธีการ: *ใช้ UBM วัดระยะดังกล่าวในผู้ที่เป็นต้อหินมุมตาปิด 50 รายเปรียบเทียบกับกลุ่มควบคุมที่ปกติ 45 ราย โดยช่องตาส่วนหน้านั้นคือระยะจากมุมตา และช่องตาส่วนหลังคือระยะจาก ciliary sulcus*

ผลการศึกษา: *ช่องตาส่วนหน้าและส่วนหลังของผู้ที่เป็นต้อหินมุมตาปิดนั้นเล็กกว่ากลุ่มควบคุมค่าทั้งสองนั้นสัมพันธ์กับลักษณะของค่ามุมตาต่าง ๆ อย่างมีนัยสำคัญ และช่องตาส่วนหน้านั้นจะยิ่งสั้นลงถ้ามีส่วนของ peripheral anterior synechia ที่มากขึ้น*

สรุป: *ค่าทั้งสองนั้นบ่งบอกถึงลักษณะของลูกตาที่เล็กในผู้ที่เป็นต้อหินมุมตาปิด อีกทั้งการวัดค่าทั้งสองนั้นไม่ยุ่งยาก จึงสามารถนำมาใช้ประเมินผู้ป่วยต้อหินมุมตาปิดได้*