Quantitative Measurements of the Ciliary Body in Eyes With Acute Primary-Angle Closure

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Purpose. To compare the structural differences of the ciliary body in patients with acute primary-angle closure (APAC) and normal subjects.

Methods. Forty-four patients with APAC in one eye and 25 eyes from 25 age-matched normal subjects were consecutively recruited. A-scan ultrasound and ultrasound biomicroscopy (UBM) measurements were performed. Ciliary body parameters including maximum ciliary body thickness (CBTmax), ciliary body thickness at point of the scleral spur (CBT0) and 1000 μm from the scleral spur (CBT1000), anterior placement of ciliary body (APCB), and trabecular–ciliary process angle (TCA), as well as biometric measurements, were measured.

Results. Average CBTmax was 0.894 ± 0.114, 0.967 ± 0.110, and 1.053 ± 0.103 mm in eyes with APAC, their fellow eyes, and normal eyes, respectively. Average CBT1000 was 0.616 ± 0.111, 0.631 ± 0.088, and 0.842 ± 0.118 mm, respectively. Average TCA was 48.10 ± 13.26°, 50.60 ± 9.08°, and 87.11 ± 20.71°, respectively. CBTmax and CBT0 were thinner in eyes with APAC compared with their fellow eyes ($P = 0.002$, $P < 0.001$). In addition, CBTmax, CBT1000, and TCA were smaller whereas APCB was larger in the fellow eyes of APAC patients compared with normal eyes ($P = 0.002$, $P < 0.001$, $P < 0.001$, $P < 0.001$). The anterior chamber depth (ACD) was smaller whereas lens thickness (LT) was larger in eyes with APAC compared with their fellow eyes ($P < 0.001$, $P = 0.036$). Smaller ACD and axial length and larger LT and lens vault were found in the fellow eyes of APAC patients compared with normal eyes ($P < 0.001$, $P < 0.001$, $P = 0.015$, $P = 0.001$).

Conclusions. Ciliary bodies were thinner and more anteriorly rotated in eyes with APAC as well as in their fellow eyes. Further studies are needed to elucidate the relationship between ciliary body parameters and mechanism of APAC.

Keywords: acute primary angle closure, ciliary body, ultrasound microscopy

Acute primary-angle closure (APAC) is an ophthalmologic emergency that can lead to vision loss in a very short time.[1] The risk of APAC has been suggested to be higher among Asians than in Caucasians.[2] However, the exact pathogenesis of APAC is still not very clear. Anatomic factors such as shorter axial length, more crowded anterior segment, and more anteriorly located lens have been reported to be associated with APAC.[3–7] In addition, altered dynamic factors such as physiological changes of the iris[8] and choroidal expansion[9,10] have also been suggested as risk factors. However, few studies have focused on the status of the ciliary body in APAC eyes.[11,12]

Ultrasound biomicroscopy (UBM) can provide high-definition images of the anterior segment, retroirideal structures, and ciliary processes, allowing reliable and repeatable quantitative measurements. Accurate measurement of the ciliary body is possible with UBM.[11–14] In our previous study, we performed ciliary body measurements in eyes with malignant glaucoma, their fellow eyes, and eyes with primary-angle closure (PAC) or primary-angle closure glaucoma (PACG).[14] Three parameters for the ciliary body thickness and the anterior extension of ciliary body were introduced.[14]

In the current study, ciliary body measurements using UBM were obtained and compared in eyes with APAC, their fellow eyes, and normal controls.

Methods

This was a prospective noninterventional observational study. All patients were recruited from the division of glaucoma in Zhongshan Ophthalmic Center of Sun Yat-sen University (Guangzhou, China) from June to December of 2014. The study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board. Informed consent was obtained from all patients. All subjects underwent detailed ocular examinations including best-corrected visual acuity (BCVA), slit-lamp examination, stereoscopic optic disc examination with a 90-diopter lens, and intraocular pressure (IOP) measurement by Goldmann applanation tonometry. Gonioscopy was performed in the dark using a Goldmann one-mirror lens at high magnification. Visual field examination was performed with the Humphrey perimetry (Swedish Interactive Threshold Algorithm [SITA] Standard 30-2 or 24-2) if the BCVA was better than 20/400.

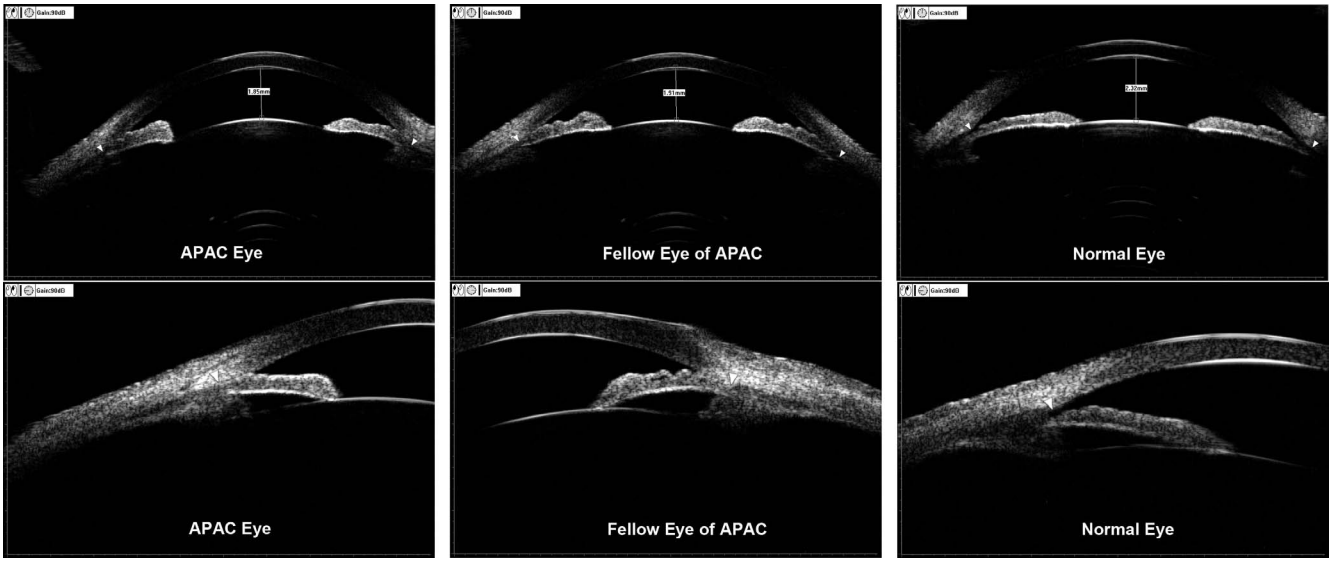

FIGURE 1. UBM images of eyes with APAC, their fellow eyes, and normal control. *Arrow*: location of the scleral spur. UBM, ultrasound biomicroscopy; APAC, acute primary-angle closure.

Patients diagnosed with APAC in one eye were consecutively recruited. The diagnosis of APAC was based on several criteria similar to those in previous studies.[7,9] These included the presence of any two of the following symptoms: ocular or periocular pain, nausea and/or vomiting; an antecedent history of intermittent blurring of vision with haloes; IOP $>$ 21 mm Hg measured by Goldmann applanation tonometry; the presence of conjunctival injection, shallow anterior chamber, and mid-dilated fixed pupil with or without corneal epithelial edema; and the presence of an occludable angle in the affected eye, as determined by gonioscopy. Exclusion criteria were secondary acute attack due to lens subluxation, uveitis, iris neovascularization, trauma, tumor, nanophthalmos, or any obvious cataract leading to an intumescent lens; diabetes or systemic hypertension; history of intraocular surgery; and inability to tolerate gonioscopy or UBM examination. The interval between acute attack of APAC and UBM examination was within 1 week. Intraocular pressure–lowering agents including topical miotics and hyperosmotics were prescribed as needed in the APAC eyes. However, no laser or surgical procedures were performed before UBM examinations. No IOP-lowering agents (including topical miotics) were applied in fellow eyes. A total of 44 patients who met the above criteria were recruited in this period.

Twenty-five eyes from 25 age-matched normal subjects followed in the same period were also consecutively recruited. Inclusion criteria of normal subjects were (1) BCVA 10/20 or better; (2) IOP $<$ 21 mm Hg by Goldmann applanation tonometry; (3) wide anterior chamber angle verified by gonioscopy; (4) normal optic nerve and macula appearance by dilated stereoscopic examination and fundus photography; (5) normal visual field; (6) no medical or family history of retinal diseases or glaucoma; (7) no medical or family history of diabetes mellitus; and (8) no prior ocular surgery.

A-scan ultrasonic biometry (model KN-3000A; Quantel Co., Ltd., Clermont-Ferrand, France) was used to measure axial length (AL) and lens thickness (LT) by one trained physician (CC) who was masked to the clinical data.

Ultrasound Biomicroscopy

Ultrasound biomicroscopy (model SW-3200L; Tianjin Suowei Electronic Technology Co., Ltd., Tianjin, China) examination and measurement were performed within 1 week of APAC diagnosis by an experienced physician (JL) who was masked to the clinical data. Subjects lay in a supine position in a dimly lit room (illumination 60–70 lux, model TES-1339; TES Electrical Electronic Corp, Tianjin, China). Radial scan images at the 12, 3, 6, and 9 o'clock positions centered over the limbus and perpendicular sulcus-to-sulcus scan over the pupillary center were obtained. When performing scans, up to 100 images could be stored as cache in the machine at a speed of 5 images/s. After image capture, the best image was selected by two experienced physicians (ZW and JL) who were both masked to the clinical data. The scan had to be centered on the pupil or over the limbus, be well circumscribed, and show corneal epithelium/endothelium, anterior lens capsule, and iris pigment epithelium. The selected images were stored in the machine (Fig. 1). Details of the UBM instruments and steps of examination were similar to those in our previous study.[14]

For ciliary body measurements, radial scans at the 12, 6, 3, and 9 o'clock positions were centered over the limbus, corresponding to the superior, inferior, nasal, and temporal quadrants. The following parameters were measured as described previously[13–15] (Fig. 2): (1) maximum ciliary body thickness (CBTmax), which was the distance from the most inner point of the ciliary processes to the inner wall of sclera or its extended line; (2) ciliary body thickness at the point of the scleral spur (CBT0) and at the distance of 1000 μm (CBT1000) from the scleral spur; (3) anterior placement of ciliary body (APCB), which was the distance from the most anterior point of ciliary body to the perpendicular line from the inner wall of the sclera passing through the scleral spur; (4) trabecular–ciliary process angle (TCA), which was the angle between the posterior corneal surface and the anterior surface of the ciliary body as described previously. For the horizontal perpendicular sulcus-to-sulcus scans centered over the pupil, central anterior chamber depth (ACD), pupil diameter (PD), anterior chamber width (ACW, defined as the distance between the nasal and the temporal scleral spur), and lens vault (LV, defined as the perpendicular distance between the anterior pole of the crystalline lens and the horizontal line joining the two scleral spurs) were also measured as described previously.[16,17] Every parameter was measured three times, with the median values recorded. The reliabilities of UBM measurements have been reported in detail in our previous study and elsewhere.[14,18]

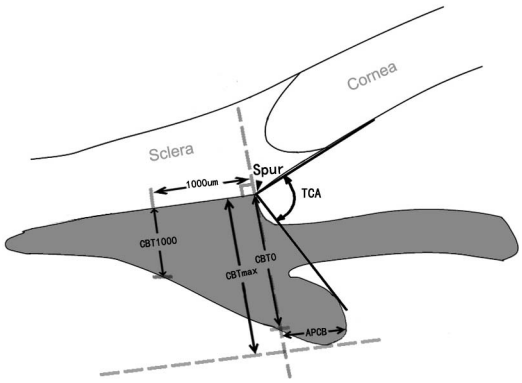

Figure 2. Determination of ciliary body parameters on ultrasound biomicroscopy. Maximum ciliary body thickness (CBTmax) is defined as the distance from the innermost point of the ciliary body to the inner wall of the sclera or its extended line.[14] Ciliary body thickness at the point of the scleral spur (CBT0)[14] and at the distance of 1000 μm (CBT1000) from the scleral spur is defined as described previously.[13] Anterior placement of ciliary body (APCB) is the distance from the most anterior point of ciliary body to the vertical line from the inner wall of the sclera through the scleral spur[14]; trabecular–ciliary angle (TCA) is the angle between the posterior corneal surface and the anterior surface of the ciliary body.[15]

Statistical Analysis

Statistical analyses were performed using SPSS software version 13.0 (SPSS, Inc., Chicago, IL, USA). The means and standard deviations of the above parameters were calculated. Paired *t*-tests were used to detect the differences between the eyes with APAC and their fellow eyes. Independent *t*-tests were used to detect the differences between the fellow eyes of APAC patients and the eyes of normal controls. Pearson correlation analysis was used to determine the relationship between biometric measurements and ciliary body parameters. $P < 0.05$ was considered statistically significant.

Results

The demographic data are shown in Table 1. There was no significant difference in age and sex between patients with APAC and normal subjects ($P = 0.444$, 0.937). The IOPs were higher, the extents of peripheral anterior synechiae (PAS) were wider, cup-to-disc (C/D) ratios were larger, and the visual field indices were worse in eyes with APAC than in their fellow eyes and in normal controls ($P = 0.000$–0.043). There was no significant difference in IOPs and C/D ratios between fellow eyes of APAC patients and normal eyes ($P = 0.881$, 0.195). Fellow eyes of APAC patients had wider extents of PAS and worse visual field indices than normal eyes ($P = 0.000$–0.008).

Axial lengths were shorter in eyes of patients with APAC compared to the normal eyes ($P < 0.001$, Table 2). Anterior chamber depths were smallest in eyes with APAC and were smaller in fellow eyes of APAC patients than in normal eyes ($P < 0.001$, Table 2). Lens thicknesses were largest in eyes with APAC, and larger in fellow eyes of APAC patients than in normal eyes ($P = 0.036$, 0.015, Table 2). There was no significant difference in LVs between eyes with APAC and their fellow eyes ($P = 0.581$), while LVs in fellow eyes of APAC patients were much larger than in normal eyes ($P = 0.001$, Table 2). Both eyes with APAC and those of normal subjects had larger pupil diameters than the fellow eyes of patients with APAC ($P = 0.027$, 0.024, Table 2).

Comparisons of the ciliary body parameters are shown in Table 3 and Figure 3. CBTmax was smallest in eyes with APAC and was smaller in fellow eyes of APAC patients than those in normal eyes ($P = 0.002$). There was no significant difference in CBT1000, APCB, and TCA between eyes with APAC and their fellow eyes ($P = 0.130$, 0.414, 0.055). CBT1000 and TCA were smaller, and APCB was larger in fellow eyes of patients with APAC than those in normal eyes ($P < 0.001$). These results suggest that the ciliary bodies in eyes with APAC were thinner and more anteriorly rotated.

Moderate to high correlations between AL/LV/ACD and the ciliary body parameters (CBTmax/CBT1000/TCA) were found ($r = 0.417$–0.765, $P < 0.001$) (Fig. 4; Table 4), suggesting that shorter axial length, shallower ACD, and greater LV were associated with thinner and more anteriorly located ciliary bodies. In addition, moderate correlations between IOP and the ciliary body thicknesses (CBTmax/CBT0/CBT1000) were also found ($r = -0.302$ to -0.339, $P = 0.001$–0.003) (Fig. 4; Table 4), indicating that higher IOP were significantly associated with thinner ciliary bodies.

Discussion

Most previous studies found that eyes with PAC had significantly shallower ACD, thicker lens, greater LV, and shorter axial length than normal eyes.[3,17] Moreover, compared with the unaffected contralateral eyes, eyes with APAC had a significantly shallower ACD, smaller chamber angle, and greater LV.[4–7] However, the status of the ciliary body in APAC eyes had not yet been fully investigated.[11,12] In the current study, biometric measurements were quantitatively compared in eyes with APAC, their fellow eyes, and normal control eyes. Similar findings on axial length, ACD, LT, and LV were demonstrated. In addition, we found that the ciliary body was anteriorly rotated and decreased in thickness in patients with APAC. For the first time, we showed that in normal subjects and patients with APAC, the shallower the ACD

Table 1. Demographics of Recruited Eyes

	APAC, $n = 44$	Fellow Eyes, $n = 44$	Normal Control, $n = 25$	*P1**	*P2*†
Age, y	61.4 ± 8.2 (39–78)		63.0 ± 8.6 (49–75)	–	0.444
Sex, male/female	5/39		3/22	–	0.937‡
Eye, OD/OS	26/18	18/26	12/13	–	0.568‡
IOP on examination, mm Hg	25.30 ± 18.42	13.04 ± 4.12	12.90 ± 3.12	<0.001	0.881
Extent of PAS, clock hours	7.4 ± 4.6	1.7 ± 2.5	0.0	<0.001	<0.001
C/D ratio	0.45 ± 0.20	0.36 ± 0.12	0.33 ± 0.06	0.006	0.195
MD of VF, dB	−9.30 ± 7.45	−7.18 ± 6.64	−3.76 ± 2.07	0.012	0.004
PSD of VF, dB	4.13 ± 2.40	3.77 ± 2.59	2.48 ± 0.95	0.043	0.008

Values within parentheses represent range. OD, right eye; OS, left eye; MD, mean deviation; VF, visual field; PSD, pattern standard deviation.
* Paired *t*-test between APAC eyes and their fellow eyes.
† Independent *t*-test between the fellow eyes and the normal control eyes.
‡ χ^2 test between patients with APAC and the normal subjects.

Table 2. Biometric Measurements of Recruited Eyes

	APAC, $n = 44$	Fellow Eyes, $n = 44$	Normal Control, $n = 25$	*P1**	*P2*†
AL, mm	22.07 ± 0.77	22.12 ± 0.85	23.36 ± 0.70	0.293	<0.001
ACD, mm	1.79 ± 0.24	1.91 ± 0.23	2.58 ± 0.24	<0.001	<0.001
PD, mm	3.84 ± 1.43	3.31 ± 1.20	4.00 ± 1.19	0.027	0.024
ACW, mm	11.90 ± 0.68	11.93 ± 0.62	11.84 ± 0.62	0.378	0.640
LT, mm	5.22 ± 0.31	5.12 ± 0.36	4.78 ± 0.53	0.036	0.015
LV, mm	1.25 ± 0.24	1.19 ± 0.17	0.63 ± 0.22	0.581	0.001

* Paired *t*-test between APAC eyes and their fellow eyes.
† Independent *t*-test between fellow eyes and normal control eyes.

is and the greater the LV is, the thinner the ciliary body is and the more it is anteriorly located.

Consistent with previous studies,[11,12,19,20] the ciliary body in APAC eyes and fellow eyes was more anteriorly rotated than that in normal eyes in the current study, which has been regarded as one of the risk factors of angle closure. However, contrary to previous UBM studies,[11,12] we found that ciliary body thickness decreased in APAC eyes and their fellow eyes. The inconsistency may arise from the qualitative character of the previous study[11] or the different method of evaluating the ciliary body.[12] In addition, our study provides novel data indicating that shallower ACDs and greater LVs are related to thinner and more anteriorly located ciliary body.

The mechanisms of acute angle closure remain to be clarified. Several factors may contribute, including pupil block, plateau iris, thick peripheral iris roll, thick and anteriorly located lens,[3–8] and increased choroidal thickness.[9,10] Recently, more and more studies have found that shallower ACD and greater LV may predispose to acute angle closure.[5–7,21] In addition, greatest choroidal thickness was found in APAC compared to other types of PAC.[9] Quigley and his colleagues[22–24] hypothesized that choroidal expansion was a potential initiator of PAC, especially for APAC and malignant glaucoma. Acute choroidal expansion coincident with increased intravitreal pressure may cause immediate increase in IOP and the forward movement of the lens, worsening pupillary block.[22–24] In our previous study, we found the ciliary body thinner and more anteriorly rotated in eyes with malignant glaucoma, which was also associated with shallower ACDs and greater LVs.[14] Similar findings were demonstrated in eyes with APAC and their fellow eyes in the

Table 3. Ciliary Body Measurements of Recruited Eyes

	APAC, $n = 44$	Fellow Eyes, $n = 44$	Normal Control, $n = 25$	*P1**	*P2*†
CBTmax, mm					
Average	0.879 ± 0.119	0.950 ± 0.122	1.057 ± 0.120	0.002	0.002
Superior	0.861 ± 0.157	0.926 ± 0.152	1.045 ± 0.150	0.038	0.001
Nasal	0.881 ± 0.154	0.952 ± 0.165	1.082 ± 0.177	0.062	0.001
Inferior	0.873 ± 0.159	0.908 ± 0.158	1.013 ± 0.127	0.503	0.002
Temporal	0.903 ± 0.162	1.012 ± 0.173	1.088 ± 0.163	0.001	0.031
CBT0, mm					
Average	0.793 ± 0.130	0.895 ± 0.116	0.945 ± 0.215	<0.001	0.304
Superior	0.794 ± 0.191	0.873 ± 0.140	0.900 ± 0.248	0.002	0.472
Nasal	0.733 ± 0.243	0.882 ± 0.167	0.996 ± 0.278	0.012	0.020
Inferior	0.803 ± 0.135	0.873 ± 0.147	0.928 ± 0.231	0.114	0.114
Temporal	0.844 ± 0.227	0.951 ± 0.169	0.955 ± 0.346	0.002	0.812
CBT1000, mm					
Average	0.597 ± 0.117	0.624 ± 0.080	0.789 ± 0.144	0.130	<0.001
Superior	0.583 ± 0.189	0.645 ± 0.147	0.821 ± 0.223	0.262	0.001
Nasal	0.634 ± 0.178	0.639 ± 0.130	0.768 ± 0.208	0.531	0.006
Inferior	0.560 ± 0.130	0.587 ± 0.103	0.741 ± 0.145	0.444	<0.001
Temporal	0.609 ± 0.167	0.626 ± 0.128	0.827 ± 0.178	0.494	<0.001
APCB, mm					
Average	0.672 ± 0.217	0.711 ± 0.188	0.414 ± 0.247	0.414	<0.001
Superior	0.693 ± 0.309	0.741 ± 0.264	0.387 ± 0.259	0.527	<0.001
Nasal	0.550 ± 0.319	0.612 ± 0.245	0.398 ± 0.244	0.662	0.002
Inferior	0.778 ± 0.263	0.752 ± 0.249	0.458 ± 0.295	0.971	<0.001
Temporal	0.667 ± 0.291	0.738 ± 0.218	0.413 ± 0.353	0.331	<0.001
TCA,°					
Average	47.48 ± 13.87	51.49 ± 10.36	81.28 ± 16.18	0.055	<0.001
Superior	42.35 ± 20.27	47.17 ± 15.17	79.20 ± 17.48	0.167	<0.001
Nasal	53.46 ± 24.69	54.89 ± 13.85	82.07 ± 18.22	0.298	<0.001
Inferior	45.31 ± 15.84	49.27 ± 13.86	80.35 ± 17.74	0.395	<0.001
Temporal	48.82 ± 17.97	54.64 ± 14.29	83.52 ± 21.20	0.027	<0.001

* Paired *t*-test between APAC eyes and their fellow eyes.
† Independent *t*-test between fellow eyes and normal control eyes.

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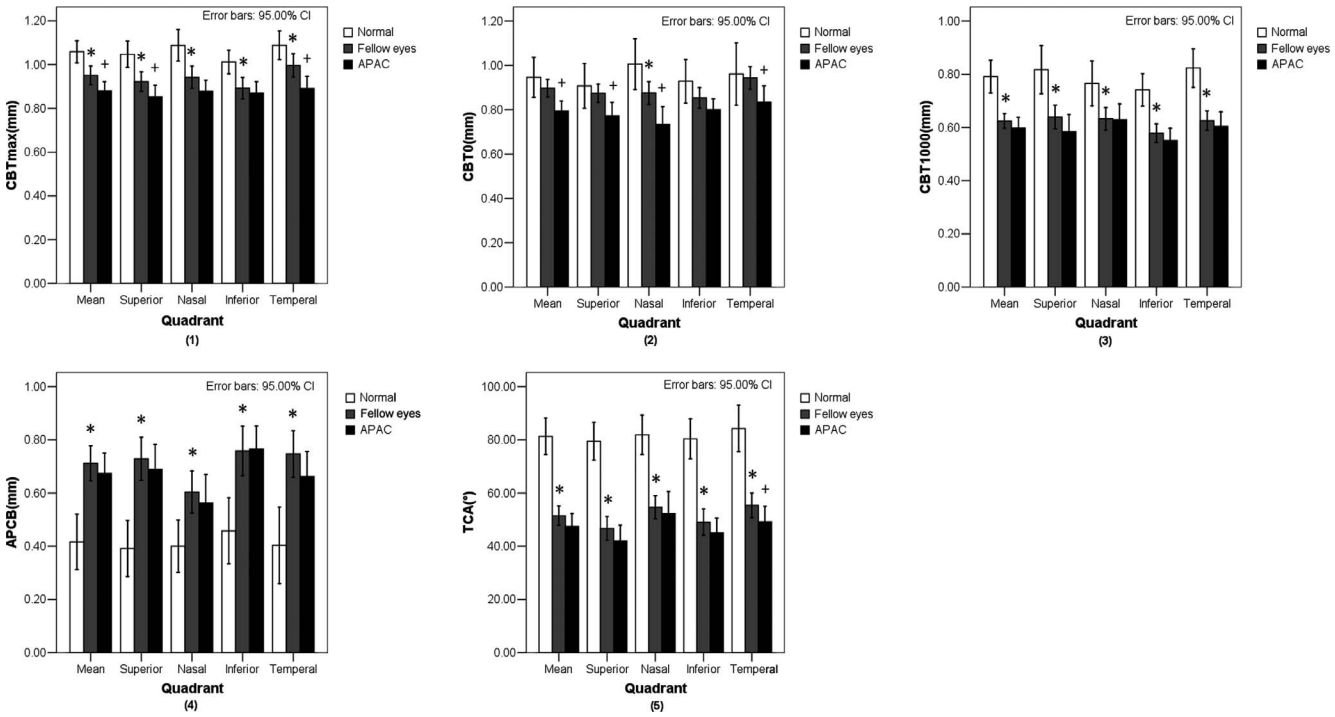

Figure 3. Comparisons of the ciliary body parameters in eyes with APAC, their fellow eyes, and normal control eyes. Compared to their fellow eyes, eyes with APAC had thinner CBTmax and CBT0 ($P < 0.01$), while no significant difference was found in CBT1000, APCB, and TCA ($P > 0.05$). Compared to normal eyes, the fellow eyes of APAC patients had thinner CBTmax and CBT1000, larger APCB, and smaller TCA in all four quadrants ($P < 0.05$). †$P < 0.05$, eyes with APAC versus their fellow eyes. *$P < 0.05$, fellow eyes versus normal eyes. *Error bars*: 95% confidence interval (95%CI). APAC, acute primary-angle closure; CBTmax, maximum ciliary body thickness; CBT0, ciliary body thickness at the point of the scleral spur; CBT1000, ciliary body thickness at the distance of 1000 μm from the scleral spur; APCB, anterior placement of the ciliary body; TCA, trabecular–ciliary angle.

current study. These findings are consistent with being the result of APAC and malignant glaucoma rather than the cause of them.

It was reported that increase of ciliary body thickness was correlated with the IOP-lowering effect of antiglaucoma drugs.[13] In the current study, though IOP-lowering agents were used in all of the APAC eyes (no laser or surgical procedures were performed), ciliary body thickness decreased in APAC eyes. Moreover, higher IOP associated with thinner ciliary body could still be detected. A previous study found similarly that increased IOP accompanied choroid thinning in PACS eyes.[25] The increase of IOP may have caused hypoperfusion of the choroid and ciliary body, resulting in decreased thicknesses.[25]

It was reported that ciliary body thickness increased by 8.3%[26] and that ACD became shallower by 4.7% after application of pilocarpine.[27] In the current study, ciliary body thickness decreased in eyes with APAC, even though pilocarpine was used. On the other hand, ACDs in eyes with APAC were shallower by 6.7% compared with their fellow eyes and were shallower by 44.1% compared with normal control, which seemed to be beyond the effect of pilocarpine.

There are several limitations to this study. First, because of the nature of the study, UBM and other ocular measurements before the onset of APAC were not available for analysis. Second, imaging during an acute attack of APAC was not obtained in the current study due to consideration for patients' safety. However, the interval between acute attack of APAC and UBM examination (less than 1 week) might be long enough that relevant anatomic information was missed. Third, the mean deviation of the fellow eyes of APAC patients was −7.18 ± 6.64 dB, which exceeded normal range. The reasons might relate to the condition of the patients, measurement error, or selection bias. Most patients with APAC were older, with

Table 4. Correlations Between Biometric Measurements and Ciliary Body Parameters of Recruited Eyes

	CBTmax		CBT0		CBT1000		TCA		APCB	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*	*r*	*P*
AL	0.437	<0.001	0.254	0.020	0.494	<0.001	0.545	<0.001	−0.237	0.030
ACD	0.453	<0.001	0.265	0.011	0.552	<0.001	0.765	<0.001	−0.121	0.250
ACW	−0.157	0.219	0.012	0.927	−0.118	0.358	0.081	0.528	−0.140	0.275
PD	0.034	0.749	0.027	0.797	0.148	0.158	0.099	0.346	−0.108	0.304
LT	−0.091	0.438	0.132	0.263	−0.125	0.290	−0.269	0.021	0.030	0.802
LV	−0.417	0.001	−0.118	0.358	−0.580	<0.001	−0.689	<0.001	0.439	<0.001
IOP	−0.312	0.002	−0.339	0.001	−0.302	0.003	−0.238	0.022	0.031	0.773
MD	−0.045	0.703	−0.079	0.505	−0.037	0.752	0.150	0.203	−0.041	0.073

r, Pearson correlation coefficient; MD, mean deviation of Humphrey visual field.

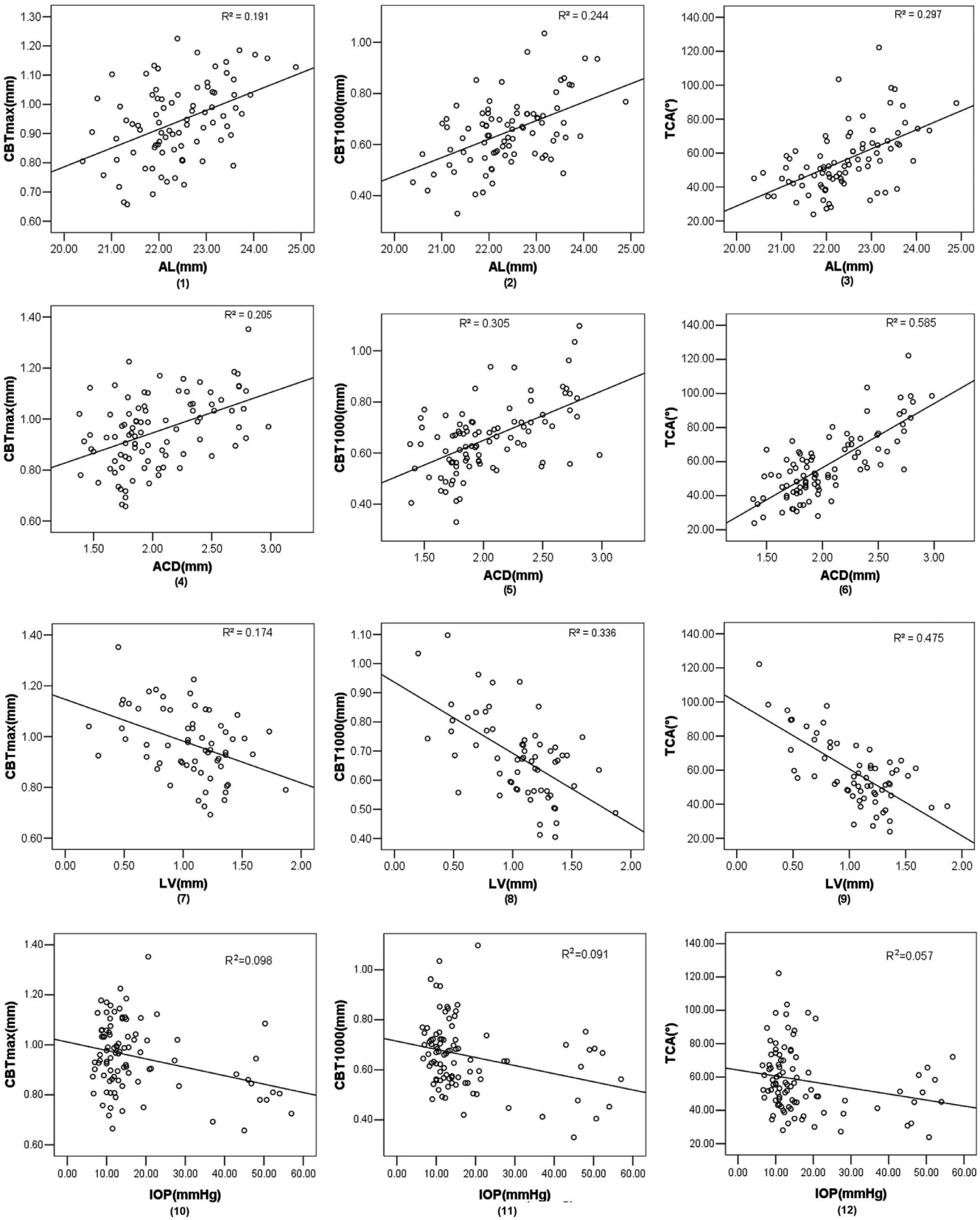

Figure 4. Scatter plots of axial length, ACD, LV, and IOP versus ciliary body parameters (CBTmax/CBT1000/TCA) in all recruited eyes. The shorter the axial length and shallower the ACD were, the thinner the CBTmax and CBT1000 and smaller the TCA were. The larger the LV and the higher the IOP were, the thinner the CBTmax and CBT1000 and smaller the TCA were. The *solid line* represents the best-fit line. R^2, coefficient of determination; AL, axial length; ACD, central anterior chamber depth; LV, lens vault; IOP, intraocular pressure; CBTmax, maximum ciliary body thickness; CBT1000, ciliary body thickness at the distance of 1000 μm; TCA, trabecular–ciliary angle.

various degrees of cataract, which might affect the Humphrey visual field mean deviation.[28,29] In addition, some patients underwent visual field examinations when the IOPs of the APAC eyes had not yet been controlled, which might also influence results of the fellow eyes. Fourth, IOP-lowering agents including topical miotics[26,27] and hyperosmotics[30] used for treatment of APAC might have affected measurements. Fifth, for correlation studies, multivariate analyses might be better. However, it was not suitable to perform multivariate analyses in the current study, as one of the preconditions of multivariate analysis is that the different groups in the sample be independent, while APAC eyes and their fellow eyes were not independent. However, our findings were clear and novel.

In summary, ciliary bodies were thinner and more anteriorly rotated in eyes with APAC and their fellow eyes, which were also associated with shallower ACDs and greater LVs. Further studies are needed to elucidate the relationship between ciliary body parameters and the mechanism of APAC.

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