Comparison of Anterior Segment-Optical Coherence Tomography Parameters in Phacomorphic Angle Closure and Acute Angle Closure Eyes

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Submitted: May 25, 2015
Accepted: October 2, 2015

Citation: Moghimi S, Ramezani F, He M, Coleman AL, Lin SC. Comparison of anterior segment-optical coherence tomography parameters in phacomorphic angle closure and acute angle closure eyes. *Invest Ophthalmol Vis Sci*. 2015;56:7611–7617. DOI:10.1167/iovs.15-17336

Purpose. The purpose of this study is to compare anterior segment-optical coherence tomography (AS-OCT) parameters in phacomorphic angle closure and acute primary angle closure (APAC) eyes.

Methods. In this cross-sectional case series, a total of 134 patients with phacomorphic angle closure (28 eyes) or APAC (54 eyes), as well as normal control subjects (52 eyes), were enrolled. Patients underwent AS-OCT imaging and A-scan biometry of both eyes. Anterior chamber depth (ACD), anterior chamber area (ACA), iris thickness (IT), iris curvature, lens vault (LV), anterior vault (AV), and angle parameters including angle opening distance (AOD 500 and AOD750) and trabecular iris space area (TISA500 and TISA750) were measured in qualified images using the Zhongshan Angle Assessment Program and compared among eyes with phacomorphic angle closure, APAC, and normal control subjects.

Results. Phacomorphic angle closure and APAC eyes had smaller AOD, ACD, ACA, ACW, AV, and posterior corneal arc length and greater LV than normal controls ($P < 0.001$ for all comparisons). After adjustment for age, sex, and pupil diameter, phacomorphic angle closure had greater AOD500 ($P = 0.02$), TISA500 ($P = 0.003$), TISA750 ($P = 0.05$), axial length ($P = 0.03$), and LV ($P = 0.001$) and less ACD ($P = 0.001$), ACA ($P = 0.003$), IT750 ($P = 0.01$), and IT2000 ($P = 0.04$) than APAC eyes: ACD < 1.59 mm (odds ratio [OR], 29.57; $P < 0.01$) and LV > 1042 μm (OR,12.12; $P < 0.01$) were the two biometric parameters that could highly discriminate phacomorphic angle closure from the APAC eyes. In multivariate analysis, ACD, LV, AOD500, and axial length could significantly distinguish the two entities.

Conclusions. Ocular biometric parameters can differentiate phacomorphic angle closure from APAC eyes. Shallower ACD and greater LV, axial length, and ACA are the main parameters that distinguish phacomorphic angle closure from APAC.

Keywords: phacomorphic glaucoma, cataract, anterior chamber depth, lens vault, iris thickness

It is predicted that in 2020, 5.3 million people will suffer from bilateral blindness due to angle closure glaucoma in the world. Primary angle closure disease is classified into different subtypes including primary angle closure suspect (PACS), acute primary angle closure (APAC), and primary angle closure glaucoma (PACG).[1] Although PACG is the main cause of bilateral blindness in Asian countries, APAC disease may lead to more severe risk of blindness unless prompt treatment is administered.[2]

Acute phacomorphic angle closure, a secondary type of angle closure disease, is still common in developing regions of the Asia where cataract extraction is not easily accessible. This condition occurs in the setting of a swollen lens, which causes acute closure of the drainage angle, leading to rapid and substantial elevation of intraocular pressure (IOP).[3,4] In the acute phase, lens swelling leads to angle closure usually in conjunction with pupillary block. However, forward movement of the peripheral iris may lead to IOP rise without pupillary block in the late phase.[5,6]

A shallow anterior chamber, thick peripheral iris, and anteriorly inserted iris are factors that make the eye more prone to an acute attack of angle closure.[7–12] Although the literature has shown an unusual greater thickness and/or anterior displacement of the crystalline lens may play a role in the development of angle closure disease, lens factors may have even more crucial roles in APAC. That might be a reason that lens extraction has been considered a treatment of choice for phacomorphic angle closure eyes and peripheral iridotomy for APAC eyes.[2,4] However, only a few studies have evaluated factors associated with phacomorphic angle closure.[5,13] Mansouri et al.[13] reported that a small anterior segment is the single most important parameter to predispose mature eyes to develop an acute attack. Both pupillary block and increasing lens vault mechanism have possible roles in the development of

phacomorphic angle closure and APAC, suggesting that lens extraction can be considered as a treatment for both conditions by addressing both mechanisms.

Recently, researchers have used anterior segment-optical coherence tomography (AS-OCT) for objective assessment of the angle, iris, and lens by obtaining an in vivo cross section of the entire anterior segment in a single image.

Lens vault (LV), one of the novel parameters measured by AS-OCT and defined as the perpendicular distance between the anterior lens pole and the horizontal line joining the temporal and nasal scleral spurs, has been associated with angle closure.[9,14–16] Moghimi et al.[15] reported that about half of the APAC cases have an exaggerated lens, in which the iris appears to drape the anterior surface of the lens, giving rise to a "volcano-like configuration" without an increase in iris curvature.

This machine also allows users to quantify the angle width and measure other anterior chamber parameters, including iris thickness and curvature, anterior chamber width (ACW), and anterior chamber area (ACA), thus helping researchers to further understand the pathogenesis of AS disease and perhaps help to predict cases in the future.[9,16–18]

The AS parameters of APAC and phacomorphic angle closure eyes—either of which can present as an acute attack—have not been compared yet. We conducted a cross-sectional study to assess the ocular biometric parameters as measured by AS-OCT and A-scan biometry, including the new parameters LV and ACW in these eyes before laser peripheral iridotomy or cataract extraction. Anterior segment, angle, iris, and lens parameters were evaluated to determine factors that can discriminate phacomorphic angle closure and acute angle closure eyes.

Methods

In this study, we enrolled consecutive patients who presented with unilateral phacomorphic angle closure (39 patients) or APAC (73 patients) to the emergency department of Farabi Eye Hospital (Tehran, Iran). Images were obtained before any therapeutic procedures were performed. The normal control subjects (56 eyes of 56 patients) were recruited from the comprehensive ophthalmology service.

The protocol for this prospective, case-control study was approved by the institutional review board of Tehran University of Medical Sciences. Written informed consent was obtained from each subject. Inclusion criteria for cases were (1) unilateral phacomorphic angle closure or APAC; (2) ability to perform testing; and (3) a broken attack after medical treatment. Exclusion criteria were (1) preexisting glaucoma; (2) history of trauma, uveitis, or surgery; or (3) any kind of laser or intraocular surgery (e.g., laser peripheral iridotomy [LPI]) in the affected eye.

Participants

An APAC was defined by the presence of the following: (1) at least two of the symptoms of an acute episode of IOP rise, which are nausea and/or vomiting, decreased vision, ocular pain or headache, and rainbow-colored halos around lights; (2) IOP at presentation of 30 mm Hg or more with Goldmann applanation tonometry; (3) signs such as corneal epithelial edema, conjunctival injection, shallow anterior chamber, and a fixed mid-dilated pupil; (4) closed angles in at least three quadrants on gonioscopic examination; and (5) narrow angle in the other eye. Phacomorphic angle closure was defined by the presence of a mature cataract in addition to criteria 1 to 4 above.

In both groups, attacks were broken with intravenous mannitol, or oral glycerin, oral acetazolamide, and topical timolol. An attack was defined as broken when IOP was less than 21 mm Hg, and the symptoms and signs of acute IOP rise had subsided. When the attack could not be broken with the described medications, the eye was excluded and treated with appropriate therapy. Miotic, mydriatic, or cycloplegic medications were not used for breaking the attack in this study.

The control subjects were included if they did not have any ocular pathology such as open or closed angle glaucoma, retinal disease, corneal opacity, or high myopia. They were required to have open angles defined as visibility of posterior trabecular meshwork in at least 180° on gonioscopy, healthy optic nerves, normal visual fields, and IOP $\leq$ 21 mm Hg.

A detailed slit-lamp examination of the anterior segment was conducted for each subject, and IOP was measured using a Goldmann applanation tonometer. Gonioscopy was performed by a Zeiss-style four-mirror gonioscopic lens (model OPDSG; Ocular Instruments, Inc., Bellevue, WA, USA) in a dark room. Narrow angle was defined in eyes with at least 180° of the posterior pigmented trabecular meshwork not visible on gonioscopy in the primary position of gaze without indentation. Stereoscopic evaluation of the optic disc using a 90-diopter (D) lens was performed. When funduscopy was not possible, B-scan ultrasonography was performed to evaluate the posterior segment. Axial length was measured by A-scan biometry (Echoscan, model U3300; Nidek, Tokyo, Japan).

Anterior Segment-OCT

A single experienced operator who was masked to the results of the clinical data performed AS-OCT (Visante OCT; Carl Zeiss Meditec, Dublin, CA, USA) on all participants under dark conditions. An enhanced AS single protocol was used, and scans were captured along the horizontal axis.

After capturing three images, the one with the best quality in terms of visualization of the scleral spurs and the central corneal reflection was chosen for analysis of AS variables.

We used the Zhongshan Angle Assessment Program (ZAAP, Guangzhou, China), which has been found to have good reproducibility for biometric measurements.[19,20] All the images were assessed for quality, and scleral spur locations were identified by the primary author (SM). We excluded images with poor quality (four images), poor perpendicularity (four images), or inability to locate scleral spurs (eight images). After the scleral spurs are identified, the software calculated the iris, cornea, and lens parameters automatically. Table 1 shows the AS-OCT parameters and their definitions[12,17,21–25] used in this study. After obtaining the images, APAC and phacomorphic angle closures eyes underwent LPI and cataract extraction, respectively, as part of their standard medical care.

Statistical Analysis

Continuous variables were analyzed using the Kruskal-Wallis test. Ocular biometric parameters were compared between APAC and phacomorphic angle closures eyes using Student's t-tests or Mann-Whitney U tests, based on normality of each variable. We used linear mixed-effects regression to control AS measurements for age, sex, and pupil diameter. In the final multivariate model, we included age, sex, pupil diameter, and those covariates with variance inflation factor less than 5 (test for collinearity) and reaching $P < 0.2$ after adjusting for age, sex, and pupil diameter. The AOD500 and IT750 were used as surrogates for angle width and iris thickness, respectively. The performance of the ocular biometric parameters in differentiating phacomorphic angle closure from APAC eyes was evaluated based on the receiver operating characteristic

Table 1. Anterior Segment Parameters Measured by AS-OCT and Their Definitions

Parameter	Definition
Anterior chamber depth (ACD)	The axial distance from the corneal endothelium to the anterior lens surface.[17]
Anterior chamber width (ACW)	The distance between the two scleral spurs.[16]
Anterior chamber area (ACA)	The cross-sectional area of the anterior chamber bordered by the posterior surface of the cornea, the anterior surface of the iris, and the anterior surface of the lens within the pupil.
Anterior chamber volume (ACV)	The software calculated this value by plotting a vertical axis through the center of the ACA and rotating ACA 360° around this vertical axis.[25]
Angle opening distance at 250, 500, and 750 μm (AOD250, AOD500, and AOD750)	The distance between the posterior corneal surface and the anterior iris surface on a line perpendicular to the trabecular meshwork, 250, 500, and 750 μm from the scleral spur, respectively.[25]
Trabecular iris space Area at 500 and 750 μm (TISA500 and TISA750)	The surface area of a trapezoid with the following boundaries: anteriorly, the angle opening distance at 500 or 750 μm from the scleral spur; posteriorly, a line drawn from the scleral spur perpendicular to the plane of the inner scleral wall to the iris; superiorly, the inner corneoscleral wall; and inferiorly, the iris surface.[25]
Iris area (I-Area)	Region defined as the cross-sectional area of the iris from the scleral spur to the pupil.[12]
Iris curvature (I-Curve)	The perpendicular distance from a line between the most central to the most peripheral points of the iris pigment epithelium to the posterior iris surface at the point of greatest convexity.[12]
Iris thickness (IT)	Iris thickness at 750 or 2000 μm from the scleral spur (IT750 and IT2000).[12]
Lens vault (LV)	The perpendicular distance from the anterior pole of the lens to the horizontal line between the scleral spurs.[9]
Anterior vault (AV)	The perpendicular distance from the corneal endothelium to the horizontal line between the scleral spurs.[21]
Posterior corneal arc length	The arc distance of the posterior corneal border between scleral spurs.[23]
Pupil diameter (PD)	The distance between the pupil edges of the iris.

(ROC) curve and the area under the curve (AUC). The best cutoff for these variables was determined based on Youden's index, and dichotomization was performed; sensitivity, specificity, and odds ratios (ORs) were calculated. Logistic regression was performed to determine the age- and sex-adjusted OR for these dichotomized variables. To determine ocular biometric parameters that were associated with AOD500 in phacomorphic angle closure and APAC eyes, linear regression was used for the two groups separately. Again, appropriate multivariate analysis including checks for multicollinearity was performed; SPSS version 18.0 (SPSS, Inc., Chicago, IL, USA) was utilized for statistical analysis, and statistical significance was set at the $P < 0.05$ level.

Results

Four cases of phacomorphic angle closure and seven eyes in the APAC group were excluded due to unbroken attacks with medication alone, and one case of phacomorphic angle closure and four cases of APAC eyes were excluded due to preexisting glaucoma. After excluding patients with poor-quality AS-OCT images (16 images), 28 phacomorphic angle closure eyes, 54 APAC eyes, and 52 normal control eyes were analyzed.

Phacomorphic angle closure subjects were older ($P = 0.005$), and there was not a significant difference in sex among the groups ($P = 0.76$). All phacomorphic angle closure and APAC eyes had narrow angles by gonioscopy. All phacomorphic angle closure eyes had mature cataracts. The angle was open in all normal control eyes. Intraocular pressure dropped from 37.5 + 13.3 and 41.2 ± 15.3 mm Hg to 13.7 + 5.6 and 12.8 + 7.2 mm Hg in the phacomorphic angle closure and APAC groups, respectively.

The mean values of the anterior segment parameters are shown in Table 2. The APAC eyes had shorter axial length than the phacomorphic angle closure and control groups. A-scan ultrasounds found shallower ACD in phacomorphic angle compared with APAC and normal eyes. (2.31 ± 0.23 versus 2.57 ± 0.47 and 3.03 ± 0.40, respectively; $P < 001$). Phacomorphic angle closure and APAC eyes had smaller angle parameters (AOD250, AOD500, AOD750, TISA500, and TISA750) and anterior chamber parameters (ACD, ACA, AV, and ACW) and greater lens vault than control eyes. Irises were thicker (IT750 and IT2000) in APAC than phacomorphic angle closure and control eyes. No significant differences were noted in iris curvature among the three groups.

Phacomorphic Angle Closure Versus APAC

Although phacomorphic angle closure eyes had greater axial length than the APAC group, smaller ACD and ACA in these eyes showed that the anterior chamber was shallower in the phacomorphic angle closure group (Table 2). There was no significant difference in posterior corneal arc length, ACW, and AV between the two groups. However, phacomorphic angle closure eyes had larger LV compared with APAC eyes (Fig.).

After adjustment for age, sex, and pupil diameter, phacomorphic angle closure eyes had wider angles (AOD500, TISA500, and TISA750) than APAC eyes. The iris thickness parameters (IT750 and IT2000) were noted to be greater in APAC eyes. However, there were no significant differences in iris steepness (I-Curve) between groups. After multivariate analysis, AOD500, ACD, axial length, and LV were the ocular biometric variables that differed significantly between the two groups (Table 2).

Table 3 summarizes the best cutoff, OR, and AUC of different biometric parameters for discrimination of phacomorphic angle closure from APAC eyes. This analysis demonstrated that ACD <1.59 mm and LV >1042 μm had the best diagnostic accuracy, with an AUC of 0.817 for both variables; ACD <1.59 mm, LV >1042 μm, ACA >10.97 mm^2, IT2000 <0.392 mm, and AL >22.43 mm had the highest ORs for distinguishing phacomorphic angle closure from APAC eyes, with ORs of 29.57, 12.12, 9.04, 5.33, and 5.04, respectively. After adjustment for age and sex, ACD <1.59 mm (ORs, 60.72;

Table 2. Univariate and Multivariate Comparison of Demographics, AS-OCT, and A-Scan Biometry Parameters in Phacomorphic Angle Closure, APAC, and Control Eyes

Parameter	Phacomorphic Angle Closure	Acute Angle Closure	Control	*P* Value for Comparison of Three Groups	*P* Value for Comparison of Phacomorphic Angle Closure and Acute Angle Closure		
					Unadjusted	Adjusted for Sex, Age, and Pupil Diameter	Multivariate
Number of eyes	28	54	52				
Age, y ± SD	73.67 ± 12.47	61.45 ± 9.48	63.90 ± 10.81	**<0.001**	**<0.001***	—	**0.007**
Sex, F/M	14/14	39/15	28/24	0.06	**0.04†**	—	0.43
IOP after breaking attack, mm Hg	13.7 + 5.6	12.8 ± 7.2	14.8 ± 2.6	0.30	0.91	—	—
Angle, closed/open	28/0	52/0	0/52	**<0.001**	1.0	—	
Axial length, mm	22.83 ± 1.21	21.92 ± 1.10	23.12 ± 0.86	**<0.001**	**0.001***	**0.03**	**0.02**
Angle parameters							
AOD250, mm	0.039 ± 0.076	0.016 ± 0.035	0.215 ± 0.124	**<0.001**	0.26†	0.08	—
AOD500, mm	0.049 ± 0.083	0.022 ± 0.042	0.299 ± 0.165	**<0.001**	0.43†	**0.02**	**0.003**
AOD750, mm	0.073 ± 0.097	0.061 ± 0.071	0.423 ± 0.222	**<0.001**	0.81†	0.10	—
TISA500, mm²	0.027 ± 0.044	0.014 ± 0.019	0.133 ± 0.097	**<0.001**	0.87†	**0.003**	—
TISA750, mm²	0.046 ± 0.066	0.027 ± 0.032	0.231 ± 0.135	**<0.001**	0.92†	**0.05**	—
Iris parameters							
IT750, mm	0.401 ± 0.119	0.481 ± 0.89	0.406 ± 0.105	**0.006**	**<0.001***	**0.01**	0.17
IT2000, mm	0.406 ± 0.114	0.460 ± 0.130	0.421 ± 0.74	**0.05**	**0.01***	**0.04**	—
I-Area, mm²	1.407 ± 0.462	1.472 ± 0.276	1.414 ± 0.212	0.12	0.11*	0.90	—
I-Curve, mm	0.321 ± 0.119	0.296 ± 0.114	0.310 ± 0.130	0.63	0.36*	0.86	—
Pupil diameter, mm	4.304 ± 1.303	4.291 ± 0.82	4.036 ± 1.008	0.35	0.64*	—	0.57
Anterior segment parameters							
ACD, mm	1.434 ± 0.436	1.86 ± 0.288	2.763 ± 0.440	**<0.001**	**<0.001†**	**0.001**	**0.001**
ACA, mm²	9.64 ± 3.99	12.33 ± 2.28	21.15 ± 4.49	**<0.001**	**<0.001†**	**0.009**	—
Lens vault, μm	1364.9 ± 351.4	1002.5 ± 271.1	391.7 ± 377.4	**<0.001**	**<0.001***	**0.001**	**0.001**
ACW , mm	11.36 ± 0.41	11.19 ± 0.48	11.55 ± 0.45	**<0.001**	0.09*	0.23	—
Anterior vault, mm	2.79 ± 0.21	2.82 ± 0.26	3.15 ± 0.19	**<0.001**	0.59*	0.46	—
Posterior corneal arc length, mm	12.81 ± 0.72	12.90 ± 0.65	13.59 ± 0.55	**<0.001**	0.52*	0.08	—

Values that are $P < 0.05$ are bold. I-Area, iris area.
* Student's *t*-test.
† Mann-Whitney *U* test.

95% CI, 8.98–410.43; $P < 0.001$) and LV >1042 μm were still the most powerful biometric parameters to discriminate phacomorphic angle closure from the APAC eyes (OR, 9.34; 95% CI, 2.13–40.85; $P = 0.003$). A similar result was found in a final multivariate model with AL, ACD, LV, and AOD500 as significant biometric discriminators of these two entities (Table 4).

The determinants of narrower angle width in the phacomorphic angle closure group were smaller ACD, smaller ACA, and greater LV. For APAC eyes, the only factor that predicted narrower angle width was a thicker iris (IT750). In the final multivariate model, the only variables that correlated with angle width were LV and IT in phacomorphic angle closure and APAC eyes, respectively (Table 5).

Discussion

Several articles have evaluated PACG and its risk factors.[7,9–12] However, the anatomic factors related to phacomorphic angle closure are not well understood. To our knowledge, this is the first study to compare the AS parameters of phacomorphic angle closure and APAC. In this study using AS-OCT, we found that phacomorphic angle closure eyes had a shallower AS, thinner iris, and greater axial length, LV, and angle. In the final multivariate analysis, ACD, axial length, LV, and trabecular angle were the parameters that could discriminate these two entities.

A lens-induced mechanism has been suggested in the development of both APAC[7–10,26] and phacomorphic angle closure.[4,6,13,27] In a cross-sectional study by Nongpiur et al.,[9] LV was found to be one of the strongest predictors of PACG. In eyes with greater LV, the iris is pushed more anteriorly, leading to a crowded angle. Moreover, recent studies have shown that LV has an important role in predisposing eyes to APAC.[7,8,10,26] Compared with normal controls, we found increased LV in both phacomorphic angle closure and APAC eyes. However, phacomorphic angle closure eyes have a mean LV that was 360 μm greater than in APAC eyes. Although increased LV has been reported with increasing age, the difference in LV in our cases reached statistical significance even after adjusting for age.

Zonular laxity and choroidal volume expansion have been proposed by some researchers as possible mechanisms for anterior lens movement in an acute attack.[28] Normally, a pupillary block mechanism is considered the primary cause of PAC, inducing iris bombe and resulting in increased iris curvature. Surprisingly, we did not find any significant difference in iris curvature among the three groups. Lee et

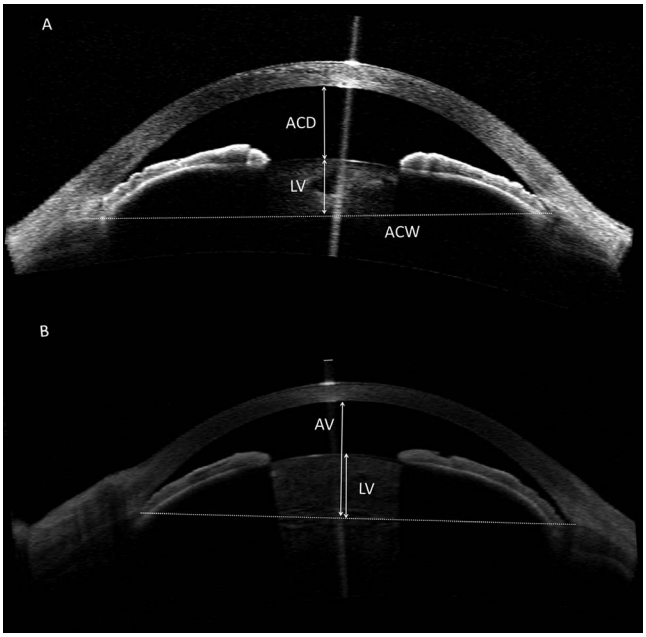

Figure. Anterior segment-OCT images of an APAC eye (**A**) and phacomorphic angle closure eye (**B**). Although the phacomorphic angle closure eye has a shallower anterior chamber and greater LV, the angles are wider. The AV and ACW are comparable.

al.[26] proposed that reduced iris curvature in an acute attack can be explained by high LV. Iris curvature might be reduced after anterior displacement of the lens leading to the volcano-type appearance of the iris.[26,29] In fact, this type of non-pupil block angle closure mechanism, called "exaggerated lens vault mechanism" has been predominant in half of the APAC eyes in a study by Moghimi et al.[15]

In the literature, ACD has been reported as a risk factor in the development of angle closure disease.[7,8,30,31] In our previous report, APAC eyes had shallower ACD than their fellow eyes and primary angle closure and PACS eyes.[8] The importance of a shallow ACD in the predisposition toward an APAC attack has also been emphasized by other investigators.[26,31]

Researchers have demonstrated that phacomorphic angle closure is a condition that can happen in eyes with both deep and shallow chambers.[27] However, Mansouri et al.[13] demonstrated that eyes with ACD <2.6 mm had an OR of 7.9 for developing phacomorphic angle closure compared with eyes that have mature cataracts. In our patients, phacomorphic angle closure eyes were 0.36 mm shallower than APAC eyes. In agreement with this finding, the anterior chamber area was less in phacomorphic angle closure subjects. Larger LV in these eyes may occupy more space in the AS, leading to decreased ACD and ACA. In the univariate analysis, ACD was the strongest variable associated with phacomorphic angle closure, and ACD <1.59 mm could be used to discriminate phacomorphic angle closure eyes from APAC eyes with a sensitivity of 84.0% and specificity of 87% (OR, 29.57). In the final multivariable model, each 0.1-mm decrease in ACD doubled the OR of being

Table 4. Results of Multivariate Logistic Regression* Demonstrating ORs and 95% CIs of Biometric Parameters for Differentiation of Phacomorphic Angle Closure and APAC Eyes

Parameter	OR	95% CI	*P* Value
Age	1.122	1.033–1.220	**0.007**
Sex	1.963	0.357–10.802	0.43
Axial length, mm	3.957	1.187–13.191	**0.02**
AOD500, mm	8.566	2.077–35.320	**0.003**
IT750, mm	0.530	0–157.4	0.57
ACD, mm	0.005	0.001–0.111	**0.001**
Lens vault, μm	1.005	1.002–1.009	**0.001**
Pupil diameter, mm	1.715	0.357–10.802	0.21

Values that are $P < 0.05$ are bold.

* Including age, sex, pupil diameter, and those variables with $P < 0.20$ in univariate analysis and variance inflation factor less than 5.

Table 3. The AUC, Best Cutoffs, and ORs of Biometric Parameters for Differentiation of Phacomorphic Angle Closure and APAC Eyes

Parameter	Area	*P* Value	Best Cutoff	OR (95% CI) For		Sensitivity	Specificity
AL, mm	0.727	**0.001**	22.43	>22.43	5.04 (1.82–13.96)	70.4	68.0
Angle parameters							
AOD250, mm	0.559	0.39	0.019	>0.019	1.94 (7.12–5.31)	35.7	67.8
AOD500, mm	0.536	0.60	0.019	>0.019	1.38 (0.54–3.51)	42.9	64.2
AOD750, mm	0.463	0.59	0.039	>0.039	0.86 (0.34–2.15)	39.3	55.6
TISA500, mm^2	0.504	0.95	0.009	>0.009	1.93 (0.76–4.88)	57.1	59.3
TISA750, mm^2	0.473	0.69	0.029	>0.029	2.00 (0.78–5.08)	50.0	66.7
Iris parameters							
IT750, mm	0.746	**0.002**	0.445	<0.445	4.04 (1.47–11.11)	75.0	57.4
IT2000, mm	0.685	**0.01**	0.392	<0.392	5.33 (1.91–14.08)	57.7	79.4
I-Area, mm^2	0.602	0.19	1.417	<1.417	2.28 (0.81–6.35)	63.6	52.8
I-Curve, mm	0.589	0.25	0.257	>0.257	2.68 (0.93–7.73)	78.6	42.3
Anterior segment parameters							
ACD, mm	0.818	**<0.001**	1.59	<1.59	29.57 (8.44–103.50)	84.0	87.0
ACA, mm^2	0.778	**<0.001**	10.97	<10.97	9.04 (3.00–27.21)	76.0	74.1
Lens vault, μm	0.818	**<0.001**	1042	>1042	12.12 (3.25–45.14)	89.3	74.1
ACW, mm	0.620	0.08	11.23	>11.23	2.61 (0.99–6.73)	68.4	57.7
Anterior vault, mm	0.536	0.59	2.84	>2.84	1.66 (0.65–4.20)	60.7	51.9
Posterior corneal arc length, mm	0.516	0.82	13.00	<13.00	1.31 (0.49–3.51)	64.0	42.6

Values that are $P < 0.05$ are bold.

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Table 5. B Values and 95% CIs of Ocular Biometric Parameters Influencing Angle Opening Distance at 500 μm (AOD500) in Phacomorphic Angle Closure and APAC Eyes

	Univariate Analysis		Multivariate Analysis*	
Parameter	**B (95% CI)**	***P* Value**	**B (95% CI)**	***P* Value**
Phacomorphic angle closure				
Axial length, mm	0.008 (−0.021 to 0.037)	0.57	—	—
IT750, mm	−0.024 (−0.258 to 0.306)	0.86	—	—
IT2000, mm	−0.002 (−0.317 to 0.313)	0.99	—	—
I-Area, mm^2	0.012 (−0.079 to 0.103)	0.78	—	—
I-Curve, mm	0.193 (−0.079 to 0.466)	0.15	0.006 (−0.107 to 0.119)	0.92
ACD, mm	0.109 (0.046-0.173)	**0.002**	−0.038 (−0.117 to 0.041)	0.33
ACA, mm^2	0.011 (0.003-0.019)	**0.007**	—	—
Lens vault, μm	−0.0001 (−0.0002 to 0)	**0.006**	−0.0001 (0.00019 to 0.00002)	**0.04**
ACW, mm	0.044 (−0.036 to 0.124)	0.26	—	—
Anterior vault, mm	0.136 (−0.015 to 0.286)	0.07	—	—
Posterior corneal arc length, mm	0.041 (−0.008 to 0.089)	0.09	0.011 (−0.020 to 0.043)	0.47
Acute primary angle closure				
Axial length, mm	0.009 (−0.003 to 0.020)	0.13	0.004 (−0.007 to 0.016)	0.43
IT750, mm	−0.129 (−0.256 to −0.002)	**0.04**	−0.185 (−0.325 to −0.045)	**0.01**
IT2000, mm	0.001 (−0.090 to 0.091)	0.98	—	—
I-Area, mm^2	−0.008 (−0.052 to 0.036)	0.70	—	—
I-Curve, mm	−0.056 (−0.162 to 0.049)	0.29	—	—
ACD, mm	0.011 (−0.032 to 0.053)	0.62	—	—
ACA, mm^2	0.003 (−0.003 to 0.008)	0.32	—	—
Lens vault, μm	−0.0004 (−0.0008 to 0)	0.06	−0.00004 (−0.0004 to 0.00009)	0.10
ACW, mm	−0.005 (−0.029 to 0.020)	0.69	—	—
Anterior vault, mm	0.032 (−0.077 to 0.012)	0.15	−0.026 (−0.075 to 0.023)	0.28
Posterior corneal arc length, mm	−0.006 (−0.024 to 0.012)	0.52	—	—

Values that are $P < 0.05$ are bold.

* Including those variables with $P < 0.20$ in univariate analysis and variance inflation factor less than 5.

phacomorphic angle closure. Among all the parameters mentioned, ACD is the most easily evaluated variable and can be assessed by available tools like A-scan ultrasonography or even estimated by slit-lamp biomicroscopy.

Although all of our phacomorphic angle closure eyes had closed angles, quantitatively we found that, after adjustment for age, sex, and pupil diameter, phacomorphic angle closure eyes had wider angles than APAC eyes. This suggests that increased lens vault in these patients may have more effect on central ACD. Anterior inclination of the iris due to exaggerated LV may secondarily reduce angle width, which might partially explain why AOD500 in these eyes correlated with ACD and ACA but not iris thickness.

For phacomorphic angle closure, Lee et al.[5] first demonstrated that eyes with AL $\leq$ 23.2 mm were 4.3 times as likely to develop phacomorphic glaucoma compared with eyes with AL $>$ 23.7 mm. Mansouri et al.[13] did not find any significant difference between mature cataracts and phacomorphic angle closures in terms of AL. They proposed that the anterior segment dimensions of the eye might play a more important role in the development of phacomorphic angle closure. In the present study, axial length of the phacomorphic angle closure eyes was greater than APAC eyes and smaller than normal control eyes. Anterior vault, ACW, and posterior corneal arc length of phacomorphic angle closure and APAC eyes, which determine the AS dimensions of the eye, were comparable but smaller than normal control eyes, supporting the findings of Mansouri et al.[13] We found that AL >22.43 mm is one of the variables that can discriminate phacomorphic angle closure from APAC eyes. Similarly, axial length can significantly distinguish these two entities in multivariate analysis.

In the literature, thicker irides or a prominent iris roll have been shown to be risk factors for development of angle closure.[24] Guzman et al.[7] compared iris thickness in different subtypes of angle closure and demonstrated that APAC eyes have thicker irides than primary angle closure/suspects. Although we have similar findings when comparing APAC and normal control subjects, our patients with phacomorphic angle closure did not have a thicker iris than normal control subjects. In fact, a negative association of AOD500 with peripheral iris thickness was only found in the APAC group. Angle width in the latter was associated with LV, ACD, and ACA but not IT. This supports the theory that the main pathology in phacomorphic angle closure is the intumescent cataract rather than the angle configuration such as in primary angle closure.[5,13]

Our study had some limitations. First of all, dynamic factors like change in iris volume were not evaluated in this study. Our study was cross-sectional, and we did not have the AS characteristics of eyes before the attack. During the attack, changes in the anterior chamber dimensions and lens thickness of the involved eye can occur, making these parameters unreliable as risk factors to study the development of phacomorphic angle closure or APAC. Moreover, there are many cases with combined lens-related and pupil block mechanisms in these two entities that may lead to overlapping of clinical signs. Also, we excluded cases in which attack was not broken medically and that might exclude more severe cases in each group. Finally, we could not assess lens thickness

accurately in mature cataracts, and the role of lens thickness in discriminating between the two groups is unclear.

In conclusion, we present new findings in AS parameters that may distinguish and predict phacomorphic angle closure and APAC. Smaller ACD was considered the most powerful parameter differentiating phacomorphic angle closure from APAC eyes. Smaller ACD and greater LV, AL, and angle opening distance were significant indicators for having phacomorphic angle closure compared with APAC.

Acknowledgments

The authors did not receive any financial support from public or private sources.

Disclosure: **S. Moghimi**, None; **F. Ramezani**, None; **M. He**, None; **A.L. Coleman**, None; **S.C. Lin**, None

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