Novel Discoveries of Anterior Segment Parameters in Fellow Eyes of Acute Primary Angle Closure and Chronic Primary Angle Closure Glaucoma

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Glaucoma is currently the leading cause of irreversible blindness worldwide. It is estimated that the condition affects 80 million people in 2020 and will increase to 112 million by 2040. A large proportion of the patients suffer from primary angle closure diseases (PACDs) in East Asia. PACDs refer to a spectrum of diseases, including primary angle closure suspect (PACS), primary angle closure (PAC), and PAC glaucoma (PACG). Among them, acute PAC (APAC) is an ophthalmic emergency characterized by a sudden episode of ocular or periorcular pain, blurred vision, headache, nausea, and/or vomiting accompanied by an IOP elevation. In contrast, patients with chronic PAC (CPAC) rarely experience the dramatic symptoms and are associated with a gradual and insidious onset. Anatomical structural differences must exist between APAC and CPAC eyes to explain their differences in presentation and clinical course.}

A number of studies have compared the anatomic structural differences in subtypes of PACDs, whereas there has been little research in comparisons between eyes with APAC and CPAC. Besides, the sequelae of the diseases such as iris atrophy and pupillary changes following APAC, and extensive peripheral anterior synechia (PAS) in CPAC could impede the measurement and evaluation of the original anatomical characteristics. The fellow eyes of APAC (F-APAC) and fellow eyes of CPACG (F-CPACG) could perform better in evaluation of the initial anatomical characteristics of APAC and CPAC, because PACDs have been described as a bilateral condition typically with asymmetric severity between eyes,
and the F-APAC and F-CPACG have been confirmed to aggra-
vo to APAC and CPACG, respectively, if not treated.13–15

A recent study compared the differences between F-APAC
and F-CPACG using ultrasound biomicroscopy (UBM), and
showed smaller anterior segment dimensions, higher lens
vault (LV), more posterior iris insertion, greater iris curva-
ture, and more anteriorly rotated ciliary body in F-APAC
compared with F-CPACG.12 However, the peripheral iris
thickness, angle width, and the area of ciliary process were
not well-studied. In this study, we used UBM to compare
anterior segment parameters between F-APAC and F-CPACG,
with a special focus on peripheral iris thickness, angle
width, and the area of ciliary process, to further investi-
gate the anatomic structural differences between APAC and
CPAC.

METHODS

Patients

This was an observational comparative study of Chinese
subjects approved by the ethics committee of Peking Univer-
sity People’s Hospital and adhering to the tenets of the
Declaration of Helsinki. Written informed consent was
obtained for all subjects.

Subjects diagnosed with APAC and CPACG were recruited
from the glaucoma clinics of Peking University People’s
Hospital from September 2016 through May 2021. A total
of 116 eyes of 116 patients were recruited from the clinic,
of whom 6 were excluded for poor UBM image quality. Finally,
110 eyes of 110 patients were enrolled.

APAC was defined as eyes with two of the following
symptoms: ocular or periocular pain, headache, nausea
and/or vomiting, blurred vision, and halos around lights;
and the following ophthalmologic findings: an IOP of more
than 30 mm Hg, conjunctival hyperemia, corneal epithe-
ilial oedema, shallow anterior chamber with angle closure,
iris bombe, and mid-dilated pupil. The fellow eyes of
APAC (F-APAC) were defined as the fellow eyes of patients
with a recent unilateral APAC that never experienced an
acute attack and showed no signs of a prior acute attack
(no PAS).

Eyes with CPACG were defined as eyes without symp-
toms or signs of a prior acute attack, including glaucomatous
fleck, keratic precipitates, or iris atrophy. Patients had more
than three cumulative clock-hours of PAS and a chronically
raised IOP (>21 mm Hg), along with glaucomatous optic neu-
ropathy or visual field defect in CPACG eyes. F-CPACG
was defined as the less severe fellow eyes of CPACG, namely,
the PACS/PAC eyes with no PAS or less than three cumulative
clock-hours of PAS without glaucomatous optic neuropathy
or visual field defect.

Based on the International Society of Geographic and
Epidemiologic Ophthalmology classification, in F-APAC and
F-CPACG, an eye with appositional contact between the
peripheral iris and the posterior trabecular meshwork was
defined as PAS; an eye with iridotrabecular contact and an
elevated IOP or PAS with no secondary cause for the PAS,
but without glaucomatous optic neuropathy was defined as
PAC.14

Exclusion criteria included (1) secondary angle closure
such as iris neovascularization, trauma, tumor, uveitis, and
lens intumescence and subluxation, (2) plateau iris and
nanophthalmos, (3) prior laser or intraocular surgery, (4)
the use of topical antiglaucoma medicine in F-APAC and F-
CPACG eyes, and (5) an inability to tolerate gonioscopy or
UBM examinations.

Ophthalmologic Examinations

Each recruited subject underwent a comprehensive ophthal-
morexico, including visual acuity, IOP measure-
ment by Goldmann applanation tonometry (Haag-Streit,
Koniz, Switzerland), slit-lamp examination, stereoscopic
evaluation of the optic disc using a 90-diopter lens (Volk
Optical, Inc., Mentor, OH). Gonioscopy was performed in
dimly lit room by a glaucoma specialist (H.J.W.) using a
Zeiss-style four-mirror gonioscopy lens (Model G-4, Volk
Optical, Inc., Mentor, OH) at 16× magnification with and
without indentation. An occludable angle was defined as
the invisibility of the posterior trabecular meshwork under
a dynamic compression technique. Axial length and flat
and steep keratometry were measured by IOLMaster biom-
etry (Carl Zeiss Meditec, Inc., Dublin, CA). Five IOLMas-
ter measurements with a signal-to-noise ratio of more
than 100 were taken, the mean of which was used for
analysis.

Ultrasound Biomicroscopy

UBM (Aviso, Quantel Medical, Inc., Bozeman, MT) measure-
ments were performed using a 50-MHz transducer by an
experienced operator (Y.Y.W.) who was masked to the
clinical data. All subjects underwent UBM examinations
in a supine position in room light (illumination 120 lux,
measured with a luminance meter [Model ST-92, Beijing
Teachers University Photoelectricity Instrument Factory,
Beijing, China]). After topical anesthesia, a plastic eyecup
containing normal saline as a coupling agent was used to
carefully separate the lids. The UBM transducer was held
perpendicular to the ocular structures at the limbal region
to be examined. Care was taken not to exert pressure on
the globe, which could cause changes in the angle config-
uration. Patients were asked to fixate with the contralat-
eral eye at a distant target on the ceiling to minimize
accommodation. Both eyes of each subject were measured
in the superior, inferior, temporal, and nasal quadrants as
well as nasal and temporal scans centered on the pupil
to obtain complete images of the anterior segment. Only
images with a clear view of the scleral spur, angle, ciliary
body, iris and anterior surface of the lens were included
for analysis.

Images of F-APAC and F-CPACG were measured quantita-
tively in all the four quadrants by a single examiner (K.Y.Y.)
masked to clinical data with an in-built caliper in the UBM
software. The scleral spur was identified based on the differ-
cential tissue density between the collagen fibers of the scle-
ral spur and the longitudinal muscle of the ciliary body. The
anterior segment parameters were measured according to
the methods of Pavlin et al.16–18 and recent studies as follow
(Figs. 1 and 2):

(1) Pupil diameter: the shortest distance between the
pupil edges of the iris cross-sections.
(2) LV: the perpendicular distance from the anterior pole
of the lens to the horizontal line between the scleral
spurs.
(3) Anterior chamber depth (ACD): the axial distance
between the corneal endothelium and the anterior
lens surface.19

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(4) Anterior chamber width (ACW): the distance between the two scleral spurs.\(^\text{20}\)
(5) Iris area: the cumulative cross-sectional area of the full length (from spur to pupil) of the iris.
(6) Iris thickness at 750 μm (IT 750) and at 2000 μm (IT 2000): iris thickness at 750 μm and 2000 μm from the scleral spur.
(7) Angle-opening distance at 500 μm (AOD 500) and at 750 μm (AOD 750): the distance between the posterior corneal surface and the anterior iris surface on a line perpendicular to the trabecular meshwork 500 μm and 750 μm from the scleral spur.\(^\text{21}\)
(8) Trabecular–iris space area at 500 μm (TISA 500) and at 750 μm (TISA 750): the area bounded anteriorly by AOD 500 and AOD 750 as determined, posteriorly by a line drawn from the scleral spur perpendicular to the plane of the inner scleral wall to the iris, superiorly by the inner corneoscleral wall, and inferiorly by the iris surface.\(^\text{21}\)
(9) Trabecular iris angle at 500 μm (TIA 500) and at 750 μm (TIA 750): the apex of the angle at the iris recess and the arms of the angle passing through a point on the trabecular meshwork at 500 μm and 750 μm from the scleral spur and the point on the iris perpendicularly opposite.
(10) Ciliary process area (CPA): a new parameter defined as the cross-sectional area of ciliary process bounded laterally by a line connecting the insertion location of iris into the ciliary body and the cross-point of a line at 500 μm from the scleral spur perpendicular to the plane of the inner scleral wall to the ciliary process, and internally by the ciliary process surface.
(11) Trabecular–ciliary angle (TCA): the angle between the posterior corneal surface and the anterior surface of the ciliary body.

All measurements of linear parameters were expressed in millimeters and angular parameters in degrees. To assess the repeatability and reproducibility of UBM measurements, 12 images were randomly selected and regraded by the same observer (K.Y.Y.) twice separated by an interval of 1 week to assess intraobserver variability, and by a second observer (S.Q.Y.) to assess interobserver variability.

**Statistical Analysis**

Statistical analysis was performed using SPSS version 23.0 (SPSS, Inc., Chicago, IL). The averages and standard deviations were calculated for continuous data. The averages of the superior, nasal, inferior, and temporal iris area were calculated and used for final analysis. Mann–Whitney U tests and χ² tests were used to compare the continuous variables and categorical variables, respectively, between F-APAC and F-CPACG. The coefficient of the intraclass correlation was used to assess the intraobserver and interobserver variability. Univariate and multivariate logistic regression analysis were performed to determine the most important parameters differentiating F-APAC and F-CPACG. Receiver operator characteristic curve was generated and the area under the receiver operator characteristic curve (AUC) was used to discriminate F-APAC from F-CPACG. The best cut-off value was determined based on Youden’s index for parameters. Spearman correlation coefficients were calculated between anterior segment parameters and IT 750, AOD750, IV, CPA,
Novel Discoveries of Fellow Eyes of APAC and CPACG

**Table 1.** Demographic Characteristics and Clinical Examination Data of Subjects

<table>
<thead>
<tr>
<th>Parameters</th>
<th>F-APAC</th>
<th>F-CPACG</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of eyes (M/F)</td>
<td>55</td>
<td>55</td>
<td>-</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years), mean ± SD</td>
<td>12/35</td>
<td>17/38</td>
<td>0.27*</td>
</tr>
<tr>
<td>Diagnosis (PACS/CPAC)</td>
<td>48/7</td>
<td>47/8</td>
<td>0.78†</td>
</tr>
<tr>
<td>AXL (mm), mean ± SD</td>
<td>22.23 ± 0.80</td>
<td>22.87 ± 1.44</td>
<td>0.432</td>
</tr>
<tr>
<td>IOP (mm Hg), mean ± SD</td>
<td>14.26 ± 3.13</td>
<td>18.05 ± 6.04</td>
<td>0.03†</td>
</tr>
<tr>
<td>Flat K (D), mean ± SD</td>
<td>45.05 ± 0.87</td>
<td>43.7 ± 1.97</td>
<td>0.149</td>
</tr>
<tr>
<td>Steep K (D), mean ± SD</td>
<td>45.92 ± 0.93</td>
<td>44.82 ± 2.33</td>
<td>0.530</td>
</tr>
<tr>
<td>C/D ratio, mean ± SD</td>
<td>0.38 ± 0.02</td>
<td>0.47 ± 0.03</td>
<td>0.057</td>
</tr>
<tr>
<td>Lens nucleus opacity (LOCS III), mean ± SD</td>
<td>2.00 ± 1.05</td>
<td>2.42 ± 1.08</td>
<td>0.287</td>
</tr>
</tbody>
</table>

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**Table 2.** Comparison of Anterior Segment Parameters Between F-APAC and F-CPACG

<table>
<thead>
<tr>
<th>Parameters</th>
<th>F-APAC</th>
<th>F-CPACG</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD (mm)</td>
<td>2.30 ± 0.77</td>
<td>2.55 ± 0.57</td>
<td>0.081</td>
</tr>
<tr>
<td>LV (mm)</td>
<td>1.01 ± 0.39</td>
<td>0.79 ± 0.31</td>
<td>0.001†</td>
</tr>
<tr>
<td>ACW (mm)</td>
<td>11.01 ± 0.55</td>
<td>10.94 ± 0.66</td>
<td>0.727</td>
</tr>
<tr>
<td>ACD (mm)</td>
<td>1.75 ± 0.25</td>
<td>1.96 ± 0.32</td>
<td>0.001*</td>
</tr>
<tr>
<td>Iris area (mm²)</td>
<td>1.88 ± 0.23</td>
<td>2.10 ± 1.56</td>
<td>0.907</td>
</tr>
<tr>
<td>IT 750 (mm)</td>
<td>0.38 ± 0.07</td>
<td>0.42 ± 0.04</td>
<td>0.001*</td>
</tr>
<tr>
<td>IT 2000 (mm)</td>
<td>0.45 ± 0.07</td>
<td>0.47 ± 0.05</td>
<td>0.141</td>
</tr>
<tr>
<td>AOD 500 (mm)</td>
<td>0.12 ± 0.06</td>
<td>0.15 ± 0.08</td>
<td>0.056</td>
</tr>
<tr>
<td>AOD 750 (mm)</td>
<td>0.15 ± 0.08</td>
<td>0.22 ± 0.11</td>
<td>0.001*</td>
</tr>
<tr>
<td>TISA 500 (mm²)</td>
<td>0.05 ± 0.02</td>
<td>0.05 ± 0.02</td>
<td>0.695</td>
</tr>
<tr>
<td>TISA 750 (mm²)</td>
<td>0.08 ± 0.03</td>
<td>0.09 ± 0.04</td>
<td>0.381</td>
</tr>
<tr>
<td>TIA 500 (°)</td>
<td>12.36 ± 5.89</td>
<td>14.42 ± 6.98</td>
<td>0.111</td>
</tr>
<tr>
<td>TIA 750 (°)</td>
<td>10.17 ± 5.46</td>
<td>14.34 ± 7.05</td>
<td>0.001†</td>
</tr>
<tr>
<td>CPA (mm²)</td>
<td>0.62 ± 0.16</td>
<td>0.54 ± 0.14</td>
<td>0.010*</td>
</tr>
<tr>
<td>TCA (°)</td>
<td>52.94 ± 10.76</td>
<td>59.49 ± 12.40</td>
<td>0.005‡</td>
</tr>
</tbody>
</table>

**Results**

A total of 110 eyes of 110 patients, 55 F-APAC and 55 F-CPACG, were enrolled. The mean age was 66.46 ± 9.34 years in F-APAC and 67.31 ± 10.52 years in F-CPACG. There were no significant differences between the two groups in terms of age, gender, diagnosis, axial length, flat and steep keratometry, cup-to-disc ratio, or lens nucleus opacity. The IOP in F-CPACG was significantly higher than that of F-APAC (P < 0.03). The demographic characteristics and clinical examination data of the two groups are summarized in Table 1.

UBM parameters used in this study were manually measured by the researcher. The intraobserver and interobserver intraclass correlation were 0.904 to 0.997 and 0.824 to 0.995, respectively (Supplementary Table S1), which demonstrated good repeatability and reproducibility of UBM measurements in this study.

The results of anterior segment UBM parameters are shown in Table 2. Compared with F-CPACG, F-APAC had larger LV and CPA, smaller ACD, thicker IT 750, smaller AOD 750, and narrower TIA 750 and TCA (P ≤ 0.01). No significant differences were found regarding pupil diameter, ACW, respectively. A P value of less than 0.05 was considered statistically significant.

**DISCUSSION**

Anterior segment structural differences between PACG eyes and normal eyes, or between APAC eyes and the fellow eyes have been studied extensively; however, few studies have been focused on the differences between fellow eyes of APAC and CPACG. The current study confirms and extends previously published research on findings of differences between F-APAC and F-CPACG, and a new parameter, CPA, is demonstrated. To our knowledge, no research has quantitatively studied this parameter previously. In addition, it is the first time that the significance of peripheral iris thickness and AOD in the development of APAC has been described.

In this study, F-APAC had more crowded anterior segment structures compared with F-CPACG. The AOD, IT 750, TIA 750, TISA 500, and TISA 750, and TICA were smaller, and LV and CPA were larger in F-APAC compared with F-CPACG. A smaller IT 750 and AOD 750, as well as a greater LV were risk factors of F-APAC. For the reason that 40% to 80% F-APAC, if untreated, will develop an acute attack in 5 to 10 years, we speculate that PAC/PAC eyes remain to be clarified. Chen et al.11 found a thinner IT 500 in F-APAC than in F-CPACG under dark condition, whereas Li et al.12 demonstrated no significant difference in IT 500 between F-APAC(G) and F-CPAC(G) and a negative correlation with ACW and CPA in the dark condition, whereas Li et al.12 demonstrated no significant difference in IT 500 between F-APAC(G) and F-CPAC(G).
Table 3. Logistic Regression Analysis of Determinants of F-APAC

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Univariate Logistic Regression</th>
<th>Multivariate Logistic Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>PD</td>
<td>0.60</td>
<td>0.34 to 1.06</td>
</tr>
<tr>
<td>LV</td>
<td>9.19</td>
<td>2.14 to 39.45</td>
</tr>
<tr>
<td>ACW</td>
<td>1.21</td>
<td>0.65 to 2.26</td>
</tr>
<tr>
<td>ACD</td>
<td>0.06</td>
<td>0.01 to 0.33</td>
</tr>
<tr>
<td>Iris area</td>
<td>0.72</td>
<td>0.29 to 1.74</td>
</tr>
<tr>
<td>IT 750</td>
<td>&lt;0.01</td>
<td>&lt;0.01 to 0.01</td>
</tr>
<tr>
<td>IT 2000</td>
<td>&lt;0.01</td>
<td>&lt;0.01 to 0.01</td>
</tr>
<tr>
<td>AOD 500</td>
<td>&lt;0.01</td>
<td>&lt;0.01 to 1.00</td>
</tr>
<tr>
<td>AOD 750</td>
<td>&lt;0.01</td>
<td>&lt;0.01 to 0.07</td>
</tr>
<tr>
<td>TISA 500</td>
<td>1.15</td>
<td>&lt;0.01 to 2647</td>
</tr>
<tr>
<td>TISA 750</td>
<td>&lt;0.01</td>
<td>&lt;0.01 to 21.67</td>
</tr>
<tr>
<td>TIA 500</td>
<td>0.95</td>
<td>0.89 to 1.01</td>
</tr>
<tr>
<td>TIA 750</td>
<td>0.89</td>
<td>0.83 to 0.96</td>
</tr>
<tr>
<td>CPA</td>
<td>31.14</td>
<td>2.04 to 475.03</td>
</tr>
<tr>
<td>TCA</td>
<td>0.95</td>
<td>0.92 to 0.99</td>
</tr>
</tbody>
</table>

*P < 0.05.

Table 4. Areas Under Curve, Best Cut-off Values, Sensitivities and Specificity of Biometric Parameters for Differentiation of F-APAC and F-CPACG

<table>
<thead>
<tr>
<th>Parameters(mm)</th>
<th>AUC</th>
<th>P Value</th>
<th>Best Cut-Off</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV</td>
<td>0.315</td>
<td>0.001*</td>
<td>0.83</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>IT 750</td>
<td>0.703</td>
<td>&lt;0.0001*</td>
<td>0.404583</td>
<td>0.759</td>
<td>0.608</td>
</tr>
<tr>
<td>AOD 750</td>
<td>0.696</td>
<td>&lt;0.0001*</td>
<td>0.12625</td>
<td>0.796</td>
<td>0.527</td>
</tr>
</tbody>
</table>

*P < 0.05.

in light condition. The discrepancy in IT 500 between these two studies may be due to the different illumination and the former included patients who had undergone laser peripheral iridotomy (LPI), which led to alteration of iris configuration. To observe the original status of anterior segment structure, eyes with prior-treatment were excluded and measurements were performed in room light in the present study. We found that F-APAC had markedly thinner IT 750 compared with F-CPACG, but no difference of IT 2000 was noted between F-APAC and F-CPACG. This finding implied that iris was just thinner at 750 μm from the sclera spur. Moreover, a thinner IT 750 was confirmed to be a risk factor for F-APAC, and the IT 750 was sensitive for discriminating F-APAC and F-CPACG (AUC, 0.703). It has been proved that up to 50% of F-APAC patients would have an acute attack within 5 years if left untreated. Thus, we proposed that, in PAC...

Table 5. Correlation Between Anterior Segment Parameters with IT 750, AOD 750, LV and CPA in All eyes

<table>
<thead>
<tr>
<th>Parameters</th>
<th>IT 750</th>
<th>AOD 750</th>
<th>LV</th>
<th>CPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD</td>
<td>0.446</td>
<td>&lt;0.001*</td>
<td>-0.14</td>
<td>0.889</td>
</tr>
<tr>
<td>LV</td>
<td>-0.058</td>
<td>0.546</td>
<td>-0.155</td>
<td>0.107</td>
</tr>
<tr>
<td>ACW</td>
<td>0.115</td>
<td>0.232</td>
<td>0.258</td>
<td>0.007*</td>
</tr>
<tr>
<td>ACD</td>
<td>0.270</td>
<td>0.004*</td>
<td>0.509</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Iris area</td>
<td>0.076</td>
<td>0.432</td>
<td>0.103</td>
<td>0.288</td>
</tr>
<tr>
<td>IT 750</td>
<td>0.636</td>
<td>&lt;0.001*</td>
<td>0.025</td>
<td>0.794</td>
</tr>
<tr>
<td>IT 2000</td>
<td>0.095</td>
<td>0.322</td>
<td>0.908</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>AOD 500</td>
<td>0.126</td>
<td>0.191</td>
<td>0.126</td>
<td>0.191</td>
</tr>
<tr>
<td>TISA 500</td>
<td>0.065</td>
<td>0.498</td>
<td>0.670</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>TISA 750</td>
<td>0.078</td>
<td>0.417</td>
<td>0.924</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>TIA 500</td>
<td>0.061</td>
<td>0.530</td>
<td>0.867</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>TIA 750</td>
<td>0.132</td>
<td>0.168</td>
<td>0.971</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>CPA</td>
<td>-0.273</td>
<td>0.005*</td>
<td>-0.276</td>
<td>0.005*</td>
</tr>
<tr>
<td>TCA</td>
<td>0.245</td>
<td>0.012*</td>
<td>0.400</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

*P < 0.05.

PD, pupil diameter.
eyes, the thinner the IT 750, the greater the risk of an acute attack.

The difference of the iris area between F-APAC and F-CPACG was not significant. This finding is not surprising, because the iris area is a cross-sectional area of the whole iris and is not indicative of iris configuration.

Extensive measurements of the anterior chamber angle parameters were performed in our study, including the AOD 500/750, TIA 500/750, and TISA 500/750. Previous studies reported acute PACG eyes with a smaller AOD 500 and TISA 500/750 compared with CPACG eyes.21,27,29 However, there was no significant difference in AOD 500 and TISA 500/750 between the F-APAC and F-CPACG in this study. These discrepant findings may be because the morphology of the angle is changing continuously in the process of PACD. The AOD 750 was smaller in F-APAC than that in F-CPACG and was found to be sensitive for discriminating F-APAC and F-CPACG (AUC, 0.696), which is inconsistent with the prior study demonstrating the AOD 750 to be the most sensitive measurement for identifying narrow angles among AOD 250/500/750, TISA 500/750, and angle recess area.28 We also demonstrated a narrower TIA 750 in F-APAC compared with F-CPACG, which is in line with prior studies.7,8 These findings revealed that the angle width was smaller in F-APAC compared with F-CPACG at 750 μm from the sclera spur; meanwhile, the iris was thinner at this location in F-APAC. We speculate that the thinner peripheral iris at 750 μm from the sclera is more likely to be pushed anteriorly and cover the near trabecular meshwork to develop an acute attack.

In agreement with previous reports, the LV was significantly greater in F-APAC than in F-CPACG in the present study.12,21,27,29 A greater LV could push the iris more anteriorly and narrow the anterior chamber angle. This finding was confirmed in our study by significantly less AOD 750 and TIA 750 in F-APAC than in F-CPACG. A greater LV could also increase iridolenticular contact and aggravate pupillary block and lead to an acute attack, as was proved in the current study that higher LV was significantly associated with F-APAC.

ACD and ACW are parameters of anterior segment dimensions. Similar to previous results, the ACD was shallower in F-APAC than in F-CPACG in this study.11,12 The shallower ACD may be partly due to a greater LV, which was proved by the positive correlation between LV and ACD in this study. We found no significant difference in ACW between groups. However, Li et al.12 reported a smaller ACW in F-APAC(G) compared with F-CPAC(G). The PAS in F-CPACG could potentially obscure the determination of scleral spur and explain this discrepancy.

The trabecular-ciliary process angle (TCA) has been regarded as an important parameter representing the anterior position of the ciliary body.30 Consistent with a previous study, a smaller TCA was found in F-APAC than in F-CPACG in current study, suggesting that the ciliary body was more anteriorly rotated in F-APAC.12 Further, we provided a new parameter, CPA, to characterize ciliary body. CPA was measured larger in F-APAC than in F-CPACG. Also, CPA was positively associated with LV and negatively correlated to TIA and AOD in the present study. Therefore, we speculated that the larger CPA may cause a loosening of zonules and a more anterior position or protrusion of the lens, consequently, push the iris forward to narrow the anterior chamber angle. In addition, a large ciliary process also might decrease the distance between the ciliary body and lens, which might induce a ciliary block and might be a potential reason for angle closure.31

A multivariable logistic regression analysis showed a greater LV and smaller IT 750 and AOD 750 were the three parameters that could differentiate F-APAC and F-CPACG. An increase in the LV and a decrease in the IT 750 and AOD 750 significantly increased the risk of F-APAC. This finding may correspond with the two different forms of angle closure. In APAC eyes, a greater LV expands the contact area between the lens and the posterior face of the iris, which increases aqueous flow resistance and generates a pressure gradient between the anterior and posterior chambers.32,33 It is easier for the pressure gradient to push the thinner peripheral iris forward to occlude the nearer trabecular meshwork and cause an acute attack. In CPACG eyes, the mechanism of angle closure may be “creeping closure” or “zipper up” for crowded angle caused by thicker peripheral iris.

A recent community-based randomized controlled trial recommended against widespread prophylactic LPI for PACS from the perspective of health economics, because of the low incidence of angle closure disease among PACS and the limited benefit of prophylactic LPI.34 The results of current study proposed that PACS/PAC eyes with a high LV, thin IT 750, and small AOD 750 deserve special attention, because they are significant risk factors for F-APAC, which confers a high risk of acute attack, and we suggested an LPI might be taken into consideration for these eyes to prevent an acute attack. A future randomized controlled trial to directly study the incidence of acute attack with and without prophylactic LPI is needed.

This study has some limitations. Owing to the nature of the UBM examination in which the patient lies a supine and presses the eyes, the UBM examination results may be affected by the examiner or the situation, despite the care taken not to press on the eyes during the UBM examination. In addition, although the intraobserver and interobserver ICCs were good, the manual subjective evaluation of UBM images may affect the measurement of parameters. Finally, this study is limited by its cross-sectional nature, and a longitudinal study would be needed to further clarify the relationships between UBM-guided anterior chamber parameters and angle closure.

In conclusion, significant differences in anterior segment UBM parameters between F-APAC and F-CPACG were detected. F-APAC had thinner peripheral iris and narrower angle width at 750 μm from the sclera spur, shallower ACD, greater LV, larger and anteriorly positioned ciliary body compared with those with F-CPACG. The IT 750, AOD 750, and LV were the three most important parameters distinguishing these two forms.

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