Narrow Angles and Angle Closure

Anatomic Reasons for Earlier Closure of the Superior Portion of the Iridocorneal Angle

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Objective: To quantitatively investigate the ultrasound biomicroscopic features of eyes with asymmetric narrowing of the iridocorneal angles.

Methods: Asymmetric angles were defined as those differing by 2 or more Shaffer grades between the superior and inferior angles. We performed ultrasound biomicroscopy on 18 eyes in 18 patients. Measurements of the following were made: the angle recess area, the triangular area bordered by the anterior iris surface, the corneal endothelium, and a line drawn from 750 µm anterior to the scleral spur; the y-intercept, the estimated angle opening distance at the level of the scleral spur; acceleration, which describes how rapidly the angle widens from the iris root; trabecular-ciliary process distance, the distance between the trabecular meshwork and the ciliary body at 500 µm anterior to the scleral spur; and angle recess–iris insertion distance, the distance between the apex of the angle recess and the iris insertion on the ciliary body face.

Results: In the superior angle, 11 eyes developed appositional closure, 10 with B-type (apposition beginning at the iris root) and 1 with S-type (apposition beginning at the line of Schwalbe). Four eyes also had apposition inferiorly (1 B-type and 3 S-types). The y-intercept, angle recess areas, trabecular-ciliary process distance, and angle recess–iris insertion distance were significantly smaller in the superior quadrant. S-type angles predominated in the inferior angle, and B-type angles did in the superior angle, indicating a more posterior insertion of the iris in the wider inferior angles.

Conclusions: Asymmetry in eyes with narrow angles occurs because of differences in iris insertion position on the ciliary body face and from asymmetry of the ciliary body position.

Arch Ophthalmol. 2007;125:734-739

Angle closure is an anatomic disorder characterized by iris apposition to the trabecular meshwork, caused by one or a combination of abnormalities in the relative or absolute sizes or positions of anterior segment structures, or by abnormal forces in the posterior segment that alter the anatomy of the anterior segment.1 Eyes with appositional angle closure are at risk for progressive trabecular damage, elevated intraocular pressure, peripheral anterior synechiae (PAS), and acute angle closure. Eyes with angle closure have important biometric differences from healthy eyes, such as a shorter corneal diameter, a shorter radius of anterior corneal curvature (steeper curvature), a shallower anterior chamber, a thicker lens, a more anteriorly positioned lens, and a shorter axial length.2

Indentation gonioscopy permits clinical differentiation between appositional closure and PAS3 and elucidation of the mechanism of angle closure.3 The angle is narrowest in the superior quadrant, and PAS form here first, though the reason for this remains unexplained.4,5

Ultrasound biomicroscopy (UBM) enables us to measure new linear and angular parameters in healthy and glaucomatous eyes.6 Light-dark provocative testing can demonstrate angle occludability.7

We previously reported that age is associated with angle narrowing in all quadrants (especially the superior quadrant), and that among patients older than 60 years, the superior angle is significantly narrower than those in the other quadrants.8 Using UBM, we quantitatively investigated the biometric parameters of the anterior segment in eyes with asymmetric angles. We hypothesized that the asymmetry was caused either by a difference in the iris insertion distance (from the iris insertion position on the ciliary body face to the apex of the angle recess) or by an asymmetry of plateau iris configuration (the plateau being more prominent superiority).
METHODS

The study protocol was approved by the institutional review board of the New York Eye and Ear Infirmary, and informed consent was obtained. Of the 117 patients screened, 18 (15.3%) were enrolled in the study. After a complete eye examination—including slitlamp biomicroscopy, intraocular pressure measurement, and darkroom gonioscopy—the subjects underwent UBM examination (Ultrasound Biomicroscope Model P40 UBM; Paradigm Medical Industries Inc, Salt Lake City, Utah) under light and dark conditions for assessment of the anterior chamber angle. Eighteen consecutive patients older than 18 years with angle asymmetry between the superior and inferior quadrants of 2 or more grades (Shaffer) were recruited. Patients who had undergone previous incisional and laser surgery were excluded. Asymmetric angles were defined as those differing by 2 or more Shaffer grades between the superior and inferior angles when the patient was in the sitting position (measured by a 4-mirror gonioscopy without pressure on the cornea, with or without a double-hump sign on indentation). Ultrasound biomicroscopy was performed with the patient in the supine position using an immersion technique and a 30-MHz transducer that provides 4 to 5 mm of tissue penetration and 50 μm of resolution.

Images were analyzed using commercially available software (UBM Pro 2000; Paradigm Medical Industries Inc, Salt Lake City, Utah) on Microsoft Windows XP. The software allows the measurement of the angle recess area in a semiautomated fashion and also allows quantitative measurement of anterior segment structures and their relationships. During calculation of the angle recess area, the program measures the angle opening distance from the base of the angle recess to 750 μm anterior to the scleral spur. Linear regression analysis performed on the contiguous angle opening distance measurements provides 2 important data: acceleration and the y-intercept. Acceleration describes how rapidly the angle widens from the root, and the y-intercept refers to the distance between the scleral spur and the iris surface along a line perpendicular to the plane of the trabecular meshwork plane, which is the estimated angle opening distance at the scleral spur. Because UBM allows placement of the trabecular meshwork plane section through a ciliary process or through the ciliary valley between them, radial scans were taken by using a typical ciliary process to show the anterior surface of the ciliary body and its relation with the posterior iris. The trabecular-ciliary process distance (TCPD; the distance between the trabecular meshwork and the anterior aspect of the ciliary process at 500 μm anterior to the scleral spur) and the angle recess–iris insertion dis...

Figure 1. An example of the analysis of the anterior chamber angle using UBM Pro 2000 software (Paradigm Medical Industries Inc, Salt Lake City, Utah). After the observer selects the scleral spur, the program automatically detects the border and calculates the angle recession area at 750 μm anterior to the scleral spur then performs linear regression analysis of consecutive angle opening distances, producing 2 figures: acceleration and the y-intercept. The equation of the linear regression is y=ax + b, where a is the acceleration and b is the y-intercept. The y-intercept is the estimated angle opening distance at the level of the scleral spur, and acceleration describes how rapidly the angle widens from the iris root.
Eighteen eyes of 18 patients (5 men and 13 women; mean age ± SD, 66.6 ± 2.6 years; 17 white patients and 1 Hispanic patient) were enrolled. The refractive error ranged from −3.5 to +2.25 diopters. The Shaffer grade difference between the superior and inferior angles was 2 grades in 16 eyes (88.8%) and 3 grades in 2 eyes (11.1%). Six patients had a double-hump sign on indentation gonioscopy. Two types of appositional angle closure were observed during the light-to-dark provocative test: S- and B-types. The B-type (aposition beginning in the angle recess) was observed in 10 (55.5%) of 18 eyes in the superior angle, while 1 (5.5%) of 18 eyes showed B-type appositional closure in the inferior angle. S-type appositional closure (closure that begins in the vicinity of the iris insertion) was observed in 1 (5.5%) of 18 eyes in the superior angle, while 1 (5.5%) of 18 eyes showed B-type appositional closure, and the development of PAS.

The formation of PAS can occur, beginning in each case at the site of appositional closure. In B-type angles, PAS can begin at the apex; while in S-type angles, PAS can start at the site of contact between the peripheral iris and the upper trabecular meshwork. The former would result in gradual anterior progression of the apparent iris insertion, while the latter would result in tented PAS of varying extent.

In our study, the y-intercept, which measures the distance between the scleral spur and the iris surface along the line perpendicular to the plane of the trabecular meshwork, was significantly shorter in the superior quadrant when compared with the inferior quadrant under dark conditions (Table 1). In the superior angle, both acceleration and the y-intercept decreased under dark conditions, though not significantly (Table 1). This suggests...
that the peripheral part of the iris, including the iris root, moved toward the trabecular meshwork plane evenly.\textsuperscript{10} More simply, the force that pushes the iris against the cornea is applied to the iris equally and makes the peripheral part of the iris closer to the cornea, giving rise to B-type angle closure or creeping angle closure, superiorly. In the inferior angle, the y-intercept increased significantly from light to dark (Table 1), while acceleration decreased significantly. This also implies an uneven distribution of force pushing the iris against the cornea or different rigidity at different locations in the iris.\textsuperscript{10} In this situation, the physical stability of the iris root may play an important role in keeping the iris away from the trabecular meshwork plane and may give rise to S-type angle closure more frequently in the inferior angles, with a potential space between the peripheral iris, root of the iris, and the cornea (\textbf{Figure 4}). Our results suggest that the superior angle was stable both in acceleration and the y-intercept during the dark provocative test, while the inferior angle showed significant change. Possible explanation for this phenomenon is that distribution of the end (or beginning) of the dilator muscles may be different between superior and inferior angles. Iris root stability and muscle distribution hypotheses are based on an assumption that there are actual differences in angle opening distance at the scleral spur level. However, the y-intercept is an estimated angle opening distance at the scleral spur and not the actual measurement. There is a possibility that the angle opening distance at the scleral spur did not change at all but that acceleration simply decreased, pivoting at the peripheral iris location.

Sihota et al\textsuperscript{21} previously reported the mean±SEM values of TCPD in the superior angle in healthy subjects to be 1.0±0.11 mm. Our study demonstrates that the TCPD in the asymmetric angles differed significantly in the superior quadrant compared with the inferior quadrant. This difference seems to be associated with relatively anteriorly positioned ciliary processes. Trabecular-ciliary process distance is influenced by the sum of 3 segments at 500 µm from the scleral spur: the angle opening distance, iris thickness, and the ciliary sulcus.\textsuperscript{22} The TCPD is therefore strongly influenced by the position of the ciliary body. B-type angle closure was observed in 10 (55.5%) of 18 eyes in the superior angle. Theoretically, the anteri-

### Table 1. Change in Anatomic Parameters in the Superior and Inferior Quadrants Under Light and Dark Conditions*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Superior</th>
<th>Inferior</th>
<th>Difference</th>
<th>( P ) Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARA, mm\textsuperscript{2}</td>
<td>Light</td>
<td>0.04 ± 0.01</td>
<td>0.07 ± 0.01</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Dark</td>
<td>0.02 ± 0.01</td>
<td>0.05 ± 0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>Y-intercept</td>
<td>Light</td>
<td>21.7 ± 15.54</td>
<td>22.08 ± 20.66</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Dark</td>
<td>4.16 ± 13.67</td>
<td>64.18 ± 15.39</td>
<td>60.02</td>
</tr>
<tr>
<td>Acceleration</td>
<td>Light</td>
<td>0.12 ± 0.03</td>
<td>0.19 ± 0.04</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Dark</td>
<td>0.07 ± 0.04</td>
<td>0.04 ± 0.03</td>
<td>−0.02</td>
</tr>
<tr>
<td>TCPD, mm</td>
<td>Light</td>
<td>0.66 ± 0.02</td>
<td>0.80 ± 0.02</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>Dark</td>
<td>0.61 ± 0.03</td>
<td>0.70 ± 0.02</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Abbreviations: ARA, angle recess area; TCPD, trabecular-ciliary process distance.

* Values are mean ± SEM, unless otherwise indicated.
† Paired \( t \) test.

### Table 2. Categorical Data of TCPD and ARIID in Different Types of Appositional Angle Closure in the Superior and Inferior Quadrants Under Dark Conditions*

<table>
<thead>
<tr>
<th>Distance</th>
<th>B-Type</th>
<th>S-Type</th>
<th>No Apposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCPD, mm</td>
<td>Superior</td>
<td>0.57 ± 0.03 (10)</td>
<td>0.61 ± 0.03 (1)</td>
</tr>
<tr>
<td></td>
<td>Inferior</td>
<td>0.60 ± 0.02 (1)</td>
<td>0.62 ± 0.03 (3)</td>
</tr>
<tr>
<td>ARIID, mm</td>
<td>Superior</td>
<td>0 (10)</td>
<td>0.27 ± 0.03 (1)</td>
</tr>
<tr>
<td></td>
<td>Inferior</td>
<td>0 (1)</td>
<td>0.29 ± 0.03 (3)</td>
</tr>
</tbody>
</table>

Abbreviations: ARIID, angle recess–iris insertion distance; TCPD, trabecular-ciliary process distance.

* Values are given as mean ± SEM (number of eyes with particular type of appositional angle closure).
orly placed ciliary process, documented by shorter TCPD in the superior angle, may cause crowding of the angle structures, resulting in PAS formation. Categorical measurement in B-type and S-type angles in the superior and inferior quadrants depicted the shortest TCPD in the superior quadrant (Table 2). For example, in an eye with an anteriorly placed ciliary process, a thickened iris under dark illumination could broaden the contact between the iris and the angle. This broadened contact could possibly encourage PAS formation and, as this continues, could lead to creeping angle closure, a condition in which PAS slowly advance forward circumferentially, gradually moving the iris insertion forward onto the trabecular meshwork. We observed that shorter ARIID in the superior angle was associated with greater incidence of B-type appositional closure. However, a longer distance was associated with S-type closure or no apposition. These findings lend support to the hypothesis that anterior placement of the ciliary process is a predisposing factor of the development of chronic creeping closure, and that a shorter distance from the trabecular meshwork to the ciliary body is associated with a greater incidence of appositional closure.

It can be argued that UBM findings cannot be simply extrapolated to gonioscopic findings, mainly because UBM is performed while the patient is supine, whereas during gonioscopy, the patient is in the sitting position. However, previous studies have observed a very high concordance between the 2 techniques when performed in a dark room.10,23

Figure 4. Eyes with B-type (A [light illumination] and B [dark illumination]) and S-type (C [light illumination] and D [dark illumination]) angle closure. Arrows indicate regions of appositional closure. The star indicates the potential space between the peripheral part of the iris, root of the iris, and trabecular meshwork.
The angle recess area, representing the relationship between the trabecular meshwork and the iris, is generally narrower in the superior quadrant than in the inferior quadrant. The TCPD, which represents the relative position of the ciliary processes, was significantly shorter in the superior angle than in the inferior angle. This suggests that ciliary body position, a shorter distance from the trabecular meshwork to the ciliary processes, plays a role in the development of angle asymmetry. Whether this asymmetry is hereditary or acquired remains to be determined.

Submitted for Publication: May 11, 2006; final revision received November 15, 2006; accepted November 17, 2006.

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Financial Disclosure: None reported.

Funding/Support: This study was supported by the Irving and Elaine Wolbrom Research Fund of the New York Glaucoma Research Institute.

Previous Presentation: This study was presented in part at the Annual Meeting of the Association for Research in Vision and Ophthalmology; May 4, 2006; Fort Lauderdale, Fla.

REFERENCES


From the Archives of the Archives

Dr Arnold Knapp presented a case in which blindness followed an operation for empyema of the frontal sinus. The patient, 50 years old, had had 5 attacks of manifest empyema of the right frontal sinus following influenza in 5 months. The anterior extremity of the middle turbinal was removed and 2 days later the sinus was operated on according to the Kuhn method; the entire anterior and inferior was removed. The disc went on to atrophy and the patient remained blind.