Narrow Angles and Angle Closure

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

Syril K. Dorairaj, MD; Celso Tello, MD; Jeffrey M. Liebmann, MD; Robert Ritch, MD

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.

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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 (Figure 1). 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) (Figure 2) and the angle recess–iris insertion dis-
tance (ARIID; the distance between the apex of the angle recess to the iris insertion on the ciliary body face) were measured.

Ultrasound biomicroscopy measurements were made by a single observer (S.K.D.) to rule out interobserver variability.\textsuperscript{14} The average of 3 measurements was considered for the study. Statistical evaluation and comparison was performed using the paired \textit{t} test (JMP, version 4; SAS Institute Inc, Cary, NC) when evaluating the differences in biometric parameters between superior and inferior angles. A \textit{P} value \textless .05 was considered to be significant.

## RESULTS

Eighteen eyes of 18 patients (5 men and 13 women; mean age \pm SD, 66.6 \pm 2.6 years; 17 white patients and 1 Hispanic patient) were enrolled. The refractive error ranged from \textminus 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 line of Schwalbe) was observed in 1 (5.5\%) of 18 eyes in the superior angle and in 3 (16.6\%) of 18 eyes in the inferior angle. Five patients had appositional closure in the light.

The angle recess area and TCPD were significantly smaller in the superior quadrant than in the inferior quadrant under light as well as in dark conditions (\textbf{Table 1}). The \textit{y}-intercept was significantly shorter in the superior quadrant than in the inferior quadrant under dark conditions, but this difference did not reach statistical significance under light conditions (\textit{P} = .81). Acceleration tended to be shorter in the superior quadrant than in the inferior quadrant under light conditions (\textit{P} = .08) but not under dark conditions (\textit{P} = .45). The ARIID was shorter in the superior angle (mean \pm SEM, 0.11 \pm 0.04 mm) than in the inferior angle (mean \pm SEM, 0.19 \pm 0.03 mm) in dark measuring. The categorical ARIID in S-type, B-type, and nonapposition angles are given in \textbf{Table 2}.

During light-to-dark provocation, the \textit{y}-intercept increased significantly in the inferior angle (\textit{P} = .03), while acceleration decreased significantly (\textit{P} = .005). The changes in these parameters were not statistically significant for the superior angle (\textbf{Table 1}).

The development of ultrasound imaging technology has revealed a lot about anterior chamber angle structures as well as their clinical implications. The superior and inferior angles were reported to be narrower than the nasal and temporal angles when measured by UBM.\textsuperscript{18} The exact mechanism of PAS formation is still uncertain in these asymmetric angles; the literature has few UBM studies on evaluating the biometric parameters comparing asymmetric angles and the relationship between these and various biometric angle parameters, types of appositional closure, and the development of PAS.

Two different anatomic patterns of appositional angle closure were described during the light and dark provocative UBM test.\textsuperscript{19} The S-type angle is characterized by appositional closure starting in the vicinity of the line of Schwalbe. In B-type angles, the closure starts in the angle recess (\textbf{Figure 3}).\textsuperscript{19,20} The differences between the 2 types were found to be related to the topology of the iris root.\textsuperscript{20} It seems likely that the physical stability of the iris root plays a role in keeping the iris away from the trabecular meshwork. A fragile iris root may be determinant in the pathophysiology of the appositional angle closure.\textsuperscript{10}

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 \textit{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 (\textbf{Table 1}). In the superior angle, both acceleration and the \textit{y}-intercept decreased under dark conditions, though not significantly (\textbf{Table 1}). This suggests

![Figure 2](https://example.com/figure2.png)

\textbf{Figure 2.} Ultrasound biomicroscopy image with measurement of trabecular-ciliary process distance (double solid arrow). The double dotted arrow shows a distance of 500 \textmu m from the scleral spur.

### Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Superior</th>
<th>Inferior</th>
</tr>
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<tbody>
<tr>
<td>ARIID</td>
<td>0.11 mm</td>
<td>0.19 mm</td>
</tr>
<tr>
<td>TCPD</td>
<td>0.11 mm</td>
<td>0.19 mm</td>
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### Table 2

<table>
<thead>
<tr>
<th>Location</th>
<th>S-Type</th>
<th>B-Type</th>
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<tbody>
<tr>
<td>ARIID</td>
<td>0.11 mm</td>
<td>0.19 mm</td>
</tr>
<tr>
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\textsuperscript{10} Peripheral anterior synechiae are found most frequently in the superior sector\textsuperscript{4,5,15,16,17} and it is believed that the superior portion of the angle is the earliest site of synechial occlusion.\textsuperscript{19}
that the peripheral part of the iris, including the iris root, moved toward the trabecular meshwork plane evenly.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.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 (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 al21 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.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 anterior
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 ARIHD 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 quadrant than in the inferior quadrant, and ARID was 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 body, or anterior placement of the ciliary process plays a role in the development of angle asymmetry. Whether this asymmetry is hereditary or acquired remains to be determined.

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Correspondence: Robert Ritch, MD, Glaucoma Service, New York Eye and Ear Infirmary, 310 E 14th St, New York, NY 10003 (ritchmd@earthlink.net).

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REFERENCES