Anatomical Changes of the Anterior Chamber Angle With Anterior-Segment Optical Coherence Tomography

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Objective: To examine the anatomical changes of the anterior chamber angle in the eyes of white patients using anterior-segment optical coherence tomography.

Method: An observational study of 122 white patients was performed to examine the changes of the iris and the anterior angle chamber using anterior-segment optical coherence tomography. Images were compared between healthy eyes of different age groups and patients with eyes having newly diagnosed ocular hypertension or glaucoma in different lighting conditions, using the interscleral spur line as a reproducible baseline.

Results: In light illumination, the iris plane was posterior to the interscleral spur line and the iris was usually flat in 91.7% of healthy eyes in young persons. In 85.0% of healthy eyes in older persons and 92.5% of eyes in the group with ocular hypertension and glaucoma, the iris plane was anterior to the interscleral spur line and the iris was usually curved forward. In the dark lighting conditions, the pupil was dilated and the iris plane was more anterior, with narrowing or loss of the angle recess. Iridotrabecular contact was present in 67.5% of healthy eyes in older persons and 77.6% of patients with ocular hypertension or glaucoma.

Conclusion: The risk of iridotrabecular contact depends on the height of the iris plane relative to the trabecular meshwork and the degree of physiological dilation of the pupil. Open or narrow angles may become closed in dark lighting conditions, which can lead to the diagnosis of angle-closure glaucoma being missed.

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The anterior chamber angle (ACA) in the human eye changes over time. At birth, it is a translucent membrane, and it widens in the first year of life. Over time, the ACA narrows with an increase in the S-type of iris configuration, a decrease in the number of iris processes, and an increase in pigmentation of the trabecular meshwork. Factors that have been recognized as affecting the angle width include age, race/ethnicity, iris color, eye dominance, corneal curvature and refraction, and illumination. These factors can predispose to iridotrabecular contact (ITC), a common feature of the various mechanisms of angle closure.

The ACA is usually assessed subjectively with gonioscopy but can vary if looking "over the hill," tilting the gonioscope, or indenting. Objectively, the angle can be assessed by contact methods such as ultrasound biomicroscopy, which provides a resolution of up to 50 µm. More recently, noncontact methods have become available to assess the angle including Schleimpflug photography and anterior-segment optical coherence tomography (OCT).

To date, 2 anterior-segment imaging devices are commercially available that use OCT as an imaging method: the slit-lamp OCT system (SL-OCT; Heidelberg Engineering, Inc, Heidelberg, Germany) and the Visante OCT anterior-segment imaging system (Carl Zeiss Meditec Inc, Dublin, California). Both image a cross section of the anterior chamber using low-coherence interferometry with infrared light (wavelength, 1310 nm) that enables a resolution of 10 to 18 µm. The advantage of these machines is that they provide a noncontact assessment of the ACA and can be performed with the patient sitting upright. The objective of this study was to examine the anatomical changes of the ACA in the eyes of white patients using anterior-segment OCT.
METHODS

This prospective observational cross-sectional study consisted of consecutive new patients in a private ophthalmic practice in Melbourne, Australia, from June 26, 2006, to June 30, 2007. From a prospective database, data were collected for white patients with healthy eyes (age, 1-30 years and 60-70 years) and patients with newly diagnosed ocular hypertension, defined as intraocular pressure (IOP) 24 mm Hg or greater, or primary glaucoma (open-angle or angle-closure), defined as an optic neuropathy with or without glaucomatous visual field loss. Patients were excluded who had undergone previous intraocular procedures such as laser iridotomy or cataract surgery or who were Asian. Informed consent was obtained for all patients, and the study was conducted in accord with the tenets of the World Medical Association Declaration of Helsinki.

The Visante OCT anterior-segment imaging system was used to obtain images of the ACA before the eye was examined and gonioscopy was performed. The eye was aligned before the images of all 4 quadrants (0°-180°, 45°-135°, 90°-270°, and 135°-315°) were obtained simultaneously in light (normal ambient room light) and dark (completely darkened room except for the light from the Visante screen) conditions. Both eyes were imaged, and if the upper eyelid obscured the image of the ACA, it was gently retracted manually, taking care to avert pressure on the globe.

Processed images of each of the 4 quadrants of the right eye were used for the study. Using commercially available software (Adobe Photoshop Elements, version 2.0; Adobe Systems, Inc, San Jose, California), the scleral spur was identified on opposite sides of the image. On each image, a line joining the tips of the scleral spur, termed the “interscleral spur line” (ISL), was drawn to delineate the trabecular meshwork anteriorly from the scleral spur posteriorly, and the images were adjusted for rotation. Using the ISL as a baseline for assessing changes of the ACA between images, I graded the images on 2 separate occasions and I was masked to the patient’s clinical findings and the previous results.

A qualitative analysis was performed to determine the level of the iris plane relative to the ISL, the curvature of the iris (flat or curved), and the presence of ITC. Iridotrabecular contact was defined as the iris touching any part of the trabecular meshwork in any 1 of the 4 quadrants. The location of ITC was divided into superior (45°, 90°, or 135°), middle (0° or 180°), and inferior (225°, 270°, or 315°). The images were compared between the different age groups, between patients with healthy eyes and those with ocular hypertension or glaucoma (OHT-GL), and between light and dark conditions. Statistical analysis was performed using commercially available software (SPSS, version 13; SPSS, Inc, Chicago, Illinois) and the χ² test.

RESULTS

One hundred twenty-two patients were examined. The demographic data are given in Table 1. In the OHT-GL group, the mean (SD) IOP when first seen was 25.7 (4.5) mm Hg (range, 12-42 mm Hg). Gonioscopy showed no peripheral anterior synchiae in the younger age group but was present in 2 of 40 patients (5.0%) in the older age group and 5 of 58 patients (8.6%) with OHT-GL.

When analyzing the anterior-segment images obtained in light conditions, in the younger age group, the iris plane was below the ISL, resulting in the anterior chamber depth (ACD) being deep. The iris plane was flat, with 3 of 24 (12.5%) curved anteriorly (Figure 1). Posterior bowing of the iris was noted in 6 of 24 patients (25.0%) in this group. In 2 of 24 patients (8.3%), at least two-thirds of the iris plane was anterior to the ISL.

In the older age group, the images obtained in light conditions showed that in 34 of 40 patients (85.0%), two-thirds of the iris plane was anterior to the ISL (P < .001), resulting in the ACD being shallower compared with those in the younger age group. The iris plane was curved anteriorly in 32 of 40 patients (80.0%) in the older age group compared with the younger age group (P < .01) (Figure 2).

The images in the OHT-GL group, obtained in light illumination, showed that in 52 of 56 patients (92.9%), two-thirds of the iris plane was anterior to the ISL (P < .001), resulting in a shallower ACD compared with those in the younger age group. In 50 of 58 patients (86.2%), the iris plane was curved anteriorly compared with those in the younger age group (P < .01).

When compared with the images obtained in the light (Figure 3A), in the dark (Figure 3B), the pupil was dilated with shortening, peripheral thickening, and an anterior bowing of the iris. This results in the entire iris plane becoming more anterior to the ISL. When at least two-thirds of the iris is at the level of or anterior to the ISL, there is narrowing or loss of the angle recess. Loss of the angle recess is characterized by anterior movement of the peripheral iris that touches the scleral spur, trabecular meshwork, or Schwalbe line. This leads to ITC (Figure 3B) or iridoscleral contact.

When comparing images obtained in light conditions, no ITC was noted in the younger age group but was noted in 4 of 40 persons (10%) in the older age group and 13 of 58 patients (22.4%) in the OHT-GL group (Table 2). In the dark conditions, no ITC was seen in the younger age group; however, many of the open angles became closed with ITC seen in 27 of 40 (67.5%) in the older age group (P < .01) and in 45 of 58 (77.6%) in the OHT-GL group (P < .001). All patients with peripheral anterior synchiae had demonstrable ITC with anterior-segment OCT, and in all patients with ITC, at least two-thirds of the iris plane was anterior to the ISL. In 3 of 58 (5.2%) in the OHT-GL group, no ITC was demonstrated in light or dark conditions. Iris touching the scleral spur (without ITC) was demonstrated in 9 of 58 eyes (15.5%) in the OHT-GL group. Iridotrabecular contact was more commonly seen in the superior than in the inferior part of the eye, with the extent of angle closure varying with no correlation with the level of IOP or sex (Table 3).

Table 1. Demographic Data

<table>
<thead>
<tr>
<th>Patients With Healthy Eyes</th>
<th>Patients With OHT-GL</th>
</tr>
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<tbody>
<tr>
<td>Age, 1-30 Years (n = 24)</td>
<td>Age, 60-70 Years (n = 40)</td>
</tr>
<tr>
<td>Age, mean (SD) [range], y</td>
<td>Age, mean (SD) [range], y</td>
</tr>
<tr>
<td>Male</td>
<td>19.8 (7.0) [1-30]</td>
</tr>
<tr>
<td>Female</td>
<td>22.3 (9)</td>
</tr>
</tbody>
</table>

Abbreviation: OHT-GL, ocular hypertension or glaucoma.
The risk of ITC depends on the height of the iris plane relative to the trabecular meshwork and the degree of physiological dilation of the pupil. Using the ISL as a reproducible baseline between images, this study showed that, compared with the younger age group, the iris plane was more frequently anterior to the ISL (ie, level with the trabecular meshwork) with a smaller ACD in the older age group and the OHT-GL group. This is probably related to the natural lens growth and to changes of the ciliary body. As the pupil dilates, the iris contracts along its plane, resulting in its becoming shorter, thicker, and convex anteriorly, causing the anterior and outward movement of the peripheral iris plane. These changes with illumination are similar to those seen with ultrasound biomicroscopy. If most of the iris plane is anterior to the ISL, ITC may occur. This was more commonly noted on the images obtained in the dark, at the superior angle, and in the older age and the OHT-GL groups. Thus, in light illumination, open or narrow angles may be closed in dark conditions. With an open angle, ITC cannot be demon-

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**Figure 1.** Example of anterior-segment optical coherence tomographic images in an 18- (A) and 24-year-old (B) patient with healthy eyes. The iris plane is flat and below the interscleral spur line (ISL).

**Figure 2.** Example of anterior-segment optical coherence tomographic images in a 62- (A) and 67-year-old (B) patient with normal eyes. The anterior chamber depth is shallower and the iris plane is curved anteriorly and above the interscleral spur line (ISL).

**Figure 3.** Anterior-segment optical coherence tomographic images of the same patient obtained in different lighting conditions. The angle is open in the light (A) but closed in the dark (B), and iridotrabecular contact is demonstrated. ISL indicates the interscleral spur line.
stated in light or dark conditions; with a closed angle, ITC can be seen in light or dark conditions. Hence, an occludable angle (ie, an angle at risk of damage) is where ITC (>90°) can be demonstrated. As the angles narrow further over time, the extent of ITC can increase. The definition of what constitutes an open or closed angle needs to be reexamined.

Iridotrabecular contact is a common feature of the various mechanisms of angle closure that can be demonstrated with anterior-segment OCT. Inasmuch as the aqueous humor can leave the eye via either the trabecular meshwork or the uveoscleral pathway, ITC can cause an elevation or fluctuation in IOP because of appositional closure. This can lead to the formation of synchiae. However, Sihota et al have shown histologically that there is damage to the trabecular meshwork as well as synchial formation in patients with chronic angle-closure glaucoma that can lead to a gradual elevation in IOP. Thus, the level of IOP may be due to a combination of both the amount of trabecular meshwork damage and the extent of angle closure (appositional or synchial). It is plausible that trabecular meshwork damage without synchial closure may be the cause of the elevation in IOP in many of the patients with OHT-GL, given the small number with peripheral anterior synchiae in this group (8.6%). In 9 patients with OHT-GL, iris contact with the scleral spur (iridoscleral contact) without ITC was demonstrated. This may cause an elevation in IOP in patients in whom aqueous outflow is more dependent on the uveoscleral pathway. Either ITC or iridoscleral contact can lead to an elevation in IOP and increase the risk of developing glaucoma.

Primary open-angle glaucoma is the most common type of glaucoma in the white population. However, this study found that in 41 of 51 patients (80.5%) with OHT-GL, angles that were open in the light were closed in the dark because of ITC. In patients with normal IOP, ITC may be an incidental finding; however, in association with OHT-GL, its presence becomes significant because it provides a pathophysiological cause for the elevation in IOP. Thus, is primary angle-closure glaucoma more common than previously thought?

Given that the diagnosis of the type of glaucoma is made on the basis of findings at gonioscopy (which is a subjective assessment of the angle), conventional gonioscopy is used to assess whether the ACA is open by looking for the pigmented trabecular meshwork. These signs can vary by looking over the hill, tilting the goniolens, or indenting, which can contribute to intraobserver and interobserver variation. Because the ACA can change in different illumination, ITC or angle closure may be missed. In the major glaucoma texts, little is written about the lighting conditions and slitlamp beam settings that can affect the ACA when performing gonioscopy.

Iridotrabecular contact or angle closure may also be missed because gonioscopy is usually poorly performed in the clinical setting. This may occur because gonioscopy is poorly taught or it is assumed that the angles are open, given that open-angle glaucoma is the most common type of primary glaucoma. Others may use the flashlight test, central ACD measurement (<2.4 mm), or the Van Herick measurement, which has 61.9% sensitivity of detecting angle closure. Hence, angle closure or ITC can be missed if gonioscopy is not performed. In view of the findings of the present study, gonioscopy should be used to assess whether the ACA is closed by looking for ITC in dark lighting conditions with a small slitlamp beam, as Barkana et al recently reported. This can be helped by assessing the height of the iris plane relative to the pigmented trabecular meshwork and looking for signs of iris touch. However, ITC was detected in 68.3% of Asian patients by using gonioscopy in a dark room compared with anterior-segment OCT. One reason for this observation is that a small amount of light is needed to assess the angle, which can influence the pupil size and angle configuration.

The strength of this study is that the OCT image is a true noncontact objective assessment of the angle. Imaging of the ACA before the patient was examined minimized bias in patient selection. The Visante OCT anterior-segment imaging system has difficulty imaging the superior part of the angle because of ptosis in the elderly, and ITC may be missed. Also, although the risk of ITC depends on the height of the iris plane relative to the trabecular meshwork, ITC may not occur in all patients when the pupils are dilated physiologically. This may be because of an abnormal iris insertion or poor

![Table 2. Incidence of ITC in Any Quadrant in the 3 Groups Studied](https://jamanetwork.com/)

<table>
<thead>
<tr>
<th>Location</th>
<th>Patients With Healthy Eyes (n=27)</th>
<th>Patients With OHT-GL (n=45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior only</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>Superior and middle</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Superior, middle, and inferior</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Middle and possibly superior (poor image superiorly)</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Inferior only</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Poor image</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Abbreviations: ITC, iridotrabecular contact; OHT-GL, ocular hypertension or glaucoma.
pupil dilation. The weakness of this study is that it is a cross-sectional study, and other studies are needed to confirm these findings and examine the natural history of ITC.

This study shows that open or narrow angles may be closed in dark lighting conditions, leading to ITC. The risk of ITC depends on the height of the iris plane relative to the trabecular meshwork and the degree of physiological dilation of the pupil. Because ITC was commonly noted in the older age group and in patients with newly diagnosed OHT-GL, and can cause the IOP to fluctuate, gonioscopy should be performed to assess whether the angle is closed by looking for ITC. Thus, is ITC a risk factor for developing elevated IOP that can lead to glaucoma, or do patients with primary open- or narrow-angle glaucoma have primary angle-closure glaucoma? Long-term longitudinal studies are needed to examine this prospectively.

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REFERENCES


Correction

Error in Text. In the Special Article titled “Commercialism, Loss of Professionalism, and the Effect on Journals” by Liesegang, published in the September issue of the Archives (2008;126[9]:1292-1295), an error occurred in the text on page 1295. The last sentence of the article should have read as follows: "Time will tell whether professionalism will reign over commercialism in medicine."