Slit Lamp–Simulated Oblique Flashlight Test in the Detection of Narrow Angles in Chinese Eyes: The Liwan Eye Study

Mingguang He,1,2 Wenyong Huang,1 David S. Friedman,3 Changfan Wu,1,4 Yingfeng Zheng,1 and Paul J. Foster2,5

PURPOSE. To assess a modified slit lamp–simulated oblique flashlight test in the identification of persons with suspected angle closure.

METHODS. Standard oblique flashlight test (SOFT) and a modified slit lamp–simulated flashlight test (SSFT) were performed on participants identified as primary angle closure suspects and controls from a population-based study. SOFT graded the iris shadow on the nasal iris as shallow, medium, and deep. SSFT measured the length of iris shadow and corneal diameter by a slit lamp graticule eyepiece after standardizing the illumination parallel to the iris plane.

RESULTS. SOFT yielded sensitivity and specificity of 76.3% and 80.7% for the detection of eyes with two or more quadrants of pigmented trabecular meshwork not observed on static gonioscopy. Proportions of subjects in the “shallow” category increased from 9.6% in Shaffer angle width grade 4 to 82.3% in grade 0 and were 72.1% in those with steep, 56.7% in those with plateau, and 13.9% in those with regular iris profiles. SSFT yielded 84.8% sensitivity and 76.7% specificity using a cutoff of 0.18 for the ratio between iris shadow length and corneal diameter. This ratio was monotonically associated with the axial anterior chamber depth, and it was significantly greater in eyes with Shaffer angle width grade lower than 2 and significantly less in eyes with Shaffer angle width grades 3 and 4. Reproducibility of SSFT was high (paired t-test, P > 0.05).

CONCLUSIONS. More accurate measurement by controlling illumination and following a more precise method to measure shadow formation may improve the performance characteristics of this test. However, this method does not appear appropriate for community-based screening because of its relatively low specificity. (Invest Ophthalmol Vis Sci. 2007;48:5459–5463) DOI:10.1167/iovs.07-0670

Instead of contrast to the pattern of disease in Europeans, primary angle closure (PAC) has a relatively high prevalence in East Asians.1,2 This may be attributable to differences in anterior chamber angle and angle anatomy characteristics. A small eye with a shallow anterior chamber, short axial length, small corneal diameter, steep curvature, and thick relatively anterior positioned lens are all considered anatomic risk factors for PAC.3–6

Although gonioscopic examination remains the reference standard for identifying narrow or closed angles, it is technically difficult and is not appropriate for large-scale screening.7,8 Other parameters, such as central anterior chamber depth (ACD) and limbus ACD, have been suggested for use in community screening.9,10 We have reported the screening efficacy of ACD measured by optical pachymetry and ultrasound biomicroscopy11 and a modified Van Herick technique in a Mongolian population.12 However, both approaches require either a slit lamp or sophisticated instruments for measurement.

The standard oblique flashlight test (SOFT) is a simple method of screening for angle closure.13 This technique has been used in several population-based studies2 and was found to work fairly well.14 However, others have reported less positive results.15,16 Some important issues with the test are variability in flashlight illumination, subjectivity in assessment of the test result, and arbitrary cutoffs used for defining at-risk eyes. To test the efficacy of this screening method when these problems are overcome, we applied a grading scheme using an oblique light at the slit lamp to standardize the illumination, and we used a slit lamp–mounted graticule to quantify the iris shadow in a population-based study of eye disease among Chinese residents of Guangzhou.

SUBJECTS AND METHODS

Approval for this study of human subjects was obtained from the Ethics Committees of the Zhongshan (China) Ophthalmic Center, the Guangzhou Liwan (China) District government, and the Clinical Governance Committee of Moorfields Eye Hospital (London, United Kingdom). The work was conducted in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from all subjects.

Detailed study procedures have been reported elsewhere.7,17 In brief, 1405 subjects aged 50 and older were enrolled from Liwan District, Guangzhou, using cluster random sampling. Static gonioscopy was performed for all subjects with the use of a Goldmann one-mirror gonio-lens. Approximate width of the peripheral drainage angle was estimated as the angle between tangent lines to the trabecular meshwork and one third the peripheral iris without indentation. The width was then recorded on a five-point scale (0°, 10°, 20°, 30°, ≥40°) in the superior and inferior quadrants. This grading of angle width was adapted from the Shaffer classification system.19 Apparent iris insertion was recorded in all four quadrants as grades A (anterior to Schwalbe line), B (behind Schwalbe line), C (at scleral spur), D (with narrow,

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visible ciliary body band), and E (very wide ciliary body band) without indentation.20

All subjects identified as having “occludable” angles (defined as posterior and usually pigmented, with trabecular meshwork not visible in two or more quadrants in right eyes) and a systematic sample (1 of 10 consecutive subjects) of subjects who did not meet these criteria for the right eyes were included for this study. The term occludable angle is synonymous with the terms primary angle closure and anatomically narrow angle. Subjects with abnormalities precluding clear visualization of the anterior chamber (e.g., pterygium, corneal opacity, iris abnormalities) and subjects who underwent surgery that changes the configuration of the anterior segment (e.g., cataract, glaucoma, laser peripheral iridotomy) were excluded. Gonioscopy was performed by an investigator (MH) as the initial examination to classify the subjects as angle-closure suspects and controls. The subsequent oblique flashlight test was performed by an examiner (CW) masked to the gonioscopy results.

Forty individual eyes were selected for evaluation of the interobserver agreement test during the initial phase of the study. We attempted to include occludable angles as much as possible during the pilot phase. Interobserver agreement after the SOFT and then the slit lamp–simulated flashlight test (SSFT) was examined independently by two ophthalmologists (WH, CW).

SOFT was conducted before SSFT, and both examinations were conducted in a semidark room. In SOFT, the flashlight beam was set parallel to the iris plane from the temporal side when the subjects looked straight ahead. Grading was in reference to the area occupied by the iris shadow on the nasal iris between the limbus and the pupil margin, as follows: shallow, iris shadow reaching the pupil margin; medium, iris shadow reaching middle of the nasal iris; deep, almost no shadow. For the SSFT, the illumination column of the slit lamp (model 900 BQ; Haag-Streit, Bern, Switzerland) was offset with the use of a vertical slit with maximal length of slit, at an axis of 90° to the microscope, and directed from the temporal side so that the illumination was parallel to the iris plane. The subject rested the chin near the illumination column (not necessarily on the middle of the chin rest) so that the illumination was parallel to the iris plane and the iris surface was in focus at the same time. The subject was then asked to look straight ahead. The objective magnification was set to ×10. A graticule mounted in a slit lamp ×10 eyepiece, measurable in 0.1 mm unit (measuring eyepiece; Haag-Streit), was used to measure the length of the iris shadow (from the limbus to the shadow border) and the diameter of cornea (limbus to limbus). The measurement was made on the horizontal meridian through the center of the pupil from 9 o’clock to 3 o’clock. The limbus was defined as the transition point between the cornea and the sclera. For those with arcus senilis, the limbus was selected as the middle of the area of arcus. The length of iris shadow was measured from the initial shadow on the nasal side of the pupil margin to the nasal limbus (Fig. 1).

Statistical Analysis

All analyses were conducted for the right eyes only. Iris shadow ratio (ISR) was calculated by the length of iris shadow (ISL) divided by limbus-to-limbus distance (LLD) (corresponding to corneal diameter; Fig. 1). The relationship between iris shadow, LLD, and ISL and gonioscopic findings was investigated using a linear regression model.

RESULTS

Study Population

One hundred eighty-six persons with appositional closure for at least 180° and 109 controls were eligible, and all eligible subjects enrolled in the study. Table 1 summarizes the demographic characteristics of cases, controls, and the population survey cohort (after excluding those who previously underwent cataract surgery). Mean age was 70 years for cases and 64 years for controls (t-test, P < 0.001). The proportion of women was greater among the cases, but this difference was of borderline significance (χ² test, P = 0.06; age-adjusted odds ratio, 1.59; P = 0.074). There were no statistically significant differences in terms of age, sex, or Shaffer angle width (P > 0.05 for all) when comparing controls with the entire population cohort.

TABLE 1. Demographics, Refraction, and Gonioscopy for Cases and Controls in Evaluation of Oblique Flashlight Test in Chinese Eyes

<table>
<thead>
<tr>
<th>Age, y (%)</th>
<th>Cases* (n = 186)</th>
<th>Controls† (n = 109)</th>
<th>Population Sample‡ (n = 1125)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50–59</td>
<td>10.8</td>
<td>39.5</td>
<td>39.6</td>
</tr>
<tr>
<td>60–69</td>
<td>37.1</td>
<td>24.8</td>
<td>27.9</td>
</tr>
<tr>
<td>70–79</td>
<td>41.4</td>
<td>35.0</td>
<td>26.0</td>
</tr>
<tr>
<td>80+</td>
<td>10.8</td>
<td>2.8</td>
<td>6.5</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>70.0 (8.7)</td>
<td>64.0 (9.6)</td>
<td>64.0 (10.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sex (%)</th>
<th>Cases* (n = 186)</th>
<th>Controls† (n = 109)</th>
<th>Population Sample‡ (n = 1125)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>54.6</td>
<td>45.0</td>
<td>46.3</td>
</tr>
<tr>
<td>Female</td>
<td>45.4</td>
<td>55.0</td>
<td>53.7</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Anterior chamber depth (mm)</th>
<th>Cases* (n = 186)</th>
<th>Controls† (n = 109)</th>
<th>Population Sample‡ (n = 1125)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD)</td>
<td>2.09 (0.20)</td>
<td>2.59 (0.36)</td>
<td>2.59 (0.29)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shaffer angle width§</th>
<th>Cases* (n = 186)</th>
<th>Controls† (n = 109)</th>
<th>Population Sample‡ (n = 1125)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>54.6</td>
<td>4.9</td>
<td>1.7</td>
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<tr>
<td>2</td>
<td>23.0</td>
<td>19.8</td>
<td>15.2</td>
</tr>
<tr>
<td>3</td>
<td>3.2</td>
<td>30.6</td>
<td>34.3</td>
</tr>
<tr>
<td>4</td>
<td>0.5</td>
<td>44.6</td>
<td>48.9</td>
</tr>
</tbody>
</table>

Data are presented as proportions over the total (by column) for right eyes only. Twenty-two subjects were dropped because of the presence of pterygium and cornea abnormalities.

* Subjects with occludable angles (posterior, usually pigmented, trabecular meshwork not visible in at least two quadrants) in right eyes.
† Systematic sample (1 in 10 consecutive) of subjects who did not meet case criteria in the right eyes.
‡ Excluded cases with aphakia/pseudophakia (44) and angle closure suspects (236) for the right eye.
§ Averages of Shaffer angle width grades in superior and inferior quadrants were taken and reclassified as follows: grade 0 = 0; grade 1 = 0.5–1; grade 2 = 1.5–2; grade 3 = 2.5–3; grade 4 = 3.5–4.
Standard Oblique Flashlight Test

Twenty-two (7.5%) subjects could not be graded using SOFT because of corneal opacity or pterygium. Seventy percent of the eyes with occludable (greater than 180°) angles were classified as shallow by SOFT (Table 2), and 20% of normal eyes were also classified as shallow. The area under the receiver operating characteristic (ROC) curve using “shallow” as the cutoff for SOFT was 0.83 (95% confidence interval [CI], 0.78 – 0.87). The requirement that three or more quadrants of pigmented trabecular meshwork not be visible on gonioscopy as the definition of occludable angles increased the sensitivity and decreased the specificity of SOFT (80.7% and 59.7%, respectively).

Average Shaffer grades in the superior and inferior quadrants were taken, and overall angle grade was reclassified as follows: grade 0, 0; grade 1, 0.5 to 1; grade 2, 1.5 to 2; grade 3, 2.5 to 3; grade 4, 3.5 to 4. The proportion of eyes graded as shallow using SOFT increased from 9.6% in Shaffer angle width grade 4 to 82.3% in grade 0. SOFT results also were associated with gonioscopic iris profiles. Proportions of the shallow category were 72.1% in steep, 56.7% in plateau, and 13.9% in regular iris profiles ($\chi^2$ test, $P \leq 0.002$).

Slit Lamp–Simulated Flashlight Test

Using SSFT, the horizontal corneal diameter (i.e., the horizontal limbus to limbus distance) was significantly smaller in subjects than in controls ($P = 0.05$). The ISR was 0.20 in subjects and 0.13 in controls ($P < 0.05$). This ratio in subjects was equivalent to one fourth of the corneal diameter and was located close to the midpoint of the nasal iris. The mean ISR (0.21) did not change significantly for the eyes with occludable angles when the more stringent definition was used (three or more quadrants with pigmented trabecular meshwork not visible), but it became greater for the eyes identified as not occludable (ratio, 0.16). Lowess smoothed curve demonstrated an inverse monotonic association between ISR and ACD (Fig. 2). Each 0.1-mm increase in anterior chamber depth corresponded to a 0.011 ratio decrease using a linear regression model ($R^2 = 0.52; \beta = -0.11; P < 0.0001$). The ISR was also associated with Shaffer angle width: the median ratio was significantly greater in eyes with Shaffer grade less than 2 and was significantly lower in those with Shaffer grades 3 and 4 (Fig. 3; Table 3). The area under the ROC curve was 0.87 (95% CI, 0.85–0.92). Sensitivity and specificity were 84.8% and 76.7% if a cutoff of 0.18 was used. They were changed to 91.4% and 71.4% with the cutoff at 0.20 and 69.5% and 91.4% if the cutoff was changed to 0.15. The area under the ROC curve was 0.94 (95% CI, 0.89–0.99) for subjects younger than 70 years, 0.85 (95% CI, 0.77–0.93) for subjects 70 years and older, and 0.92 (95% CI, 0.87–0.97) for men and 0.85 (95% CI, 0.80–0.91) for women.

Reproducibility of Slit Lamp–Simulated Flashlight Test

Forty-two patients were recruited for an evaluation of interobserver agreement, with 12 (28.6%) eyes classified on gonioscopy as having two or more quadrants with obscured trabecular meshwork. The weighted kappa value in three categories of grading was 0.74 ($P < 0.01$) in SOFT. In SSFT, graticule units

### Table 2. Association of Standard Oblique Flashlight Test Gradings and Gonioscopic Findings in Chinese Subjects

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Deep</th>
<th>Medium</th>
<th>Shallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaffer angle width*</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>0</td>
<td>34</td>
<td>0</td>
<td>17.7</td>
<td>82.3</td>
</tr>
<tr>
<td>1</td>
<td>105</td>
<td>1.9</td>
<td>20.0</td>
<td>78.1</td>
</tr>
<tr>
<td>2</td>
<td>62</td>
<td>1.6</td>
<td>46.8</td>
<td>51.6</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>18.9</td>
<td>46.0</td>
<td>35.1</td>
</tr>
<tr>
<td>4</td>
<td>52</td>
<td>57.7</td>
<td>32.7</td>
<td>9.6</td>
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<tr>
<td>Pigmented TM not visible in two or more quadrants†</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>186</td>
<td>1.6</td>
<td>22.0</td>
<td>76.3</td>
</tr>
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<td>No</td>
<td>109</td>
<td>33.9</td>
<td>46.8</td>
<td>19.3</td>
</tr>
<tr>
<td>Pigmented TM not visible in three or more quadrants†</td>
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<td></td>
<td></td>
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<tr>
<td>Yes</td>
<td>109</td>
<td>2.8</td>
<td>16.5</td>
<td>80.7</td>
</tr>
<tr>
<td>No</td>
<td>186</td>
<td>19.9</td>
<td>39.8</td>
<td>40.3</td>
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<tr>
<td>Iris profile</td>
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<td>Regular</td>
<td>65</td>
<td>46.2</td>
<td>40.0</td>
<td>13.9</td>
</tr>
<tr>
<td>Plateau</td>
<td>67</td>
<td>7.5</td>
<td>35.8</td>
<td>56.7</td>
</tr>
<tr>
<td>Queer</td>
<td>2</td>
<td>100</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Steep</td>
<td>161</td>
<td>1.8</td>
<td>26.1</td>
<td>72.1</td>
</tr>
<tr>
<td>Anterior chamber depth (mm)</td>
<td>—</td>
<td>2.87 (0.32)</td>
<td>2.40 (0.23)</td>
<td>2.06 (0.20)</td>
</tr>
</tbody>
</table>

Data are presented as proportions by row.

* Gonioscopic grading data were missing in five cases.

† Based on apparent iris insertion using static gonioscopy.
of shallow length were 13.4 ± 0.7 units for the first observer and 13.2 ± 0.8 units for the second observer, respectively (paired t-test; \( P = 0.803 \)). This agreement remained the same for occludable angle eyes and control eyes (paired t-test; \( P = 0.942 \) for occludable; \( P = 0.694 \) for control). ISRs were 0.32 ± 0.018 and 0.33 ± 0.019, respectively, without a statistically significant difference between the first and second observers (paired t-test; \( P = 0.694 \)).

**DISCUSSION**

SOFT is quick, simple, and requires only a flashlight. Previous reports of this approach have reported both good and poor screening performance. Early publications describe 89% sensitivity and 88% specificity on identifying those with ACD of 2 mm or less.\(^ {13} \) Subsequently, this method has been used to estimate ACD in Asia, Europe, and North America.\(^ {2,21,22} \) One study from south India reported very low sensitivity (45%) using SOFT.\(^ {15} \) In contrast, researchers in China reported greater than 90% sensitivity and specificity identifying temporal Shaffer grade ≤2 when performing SOFT using standard photographs based on the ratio of iris shadow to corneal diameter and classifying subjects according to four grades.\(^ {2,5} \) No masking was used in this study, and this might have resulted in better performance of the test. We confirm that SOFT had a relatively high sensitivity (76.5%) in our Chinese population while maintaining 80.7% specificity when observers were masked. However, when we used a more stringent definition for occludable angles (requiring three quadrants of pigmented trabecular meshwork not seen), test specificity declined to 60%. Given this finding, the precise approach used to define the condition of interest clearly has a strong impact on the screening effectiveness of this test.

One explanation for why SOFT might perform differently in dissimilar study populations is that the efficacy of SOFT may depend on the mechanism of angle closure, anterior segment anatomy and other unknown factors. Van Herick\(^ {10} \) pointed out that the flashlight method may be subject to misclassification in eyes with either plateau iris configuration or with central shallowing of the anterior chamber but wide drainage angles. We demonstrated a lower rate of shallow category in subjects with gonioscopically confirmed plateau iris configuration (based on the appearance of the anterior surface of the iris) than in those with a steep iris profile.

Our attempt to improve the flashlight test by using a gradable at the slit lamp improved performance slightly (but not significantly), with the area under the ROC curve increasing from 0.83 with SOFT to 0.89 with the slit lamp method. The slit lamp method was able to identify more than 90% of cases while maintaining a specificity of 71%, but the cutoffs selected were chosen in a post hoc analysis; performance would likely not have been as good in a different population. Because the gradable method requires a slit lamp, the limited increase in diagnostic accuracy does not appear to justify widespread use in screening.

The length of iris shadow was monotonically related to ACD. However, the association between the length of iris shadow and gonioscopic angle width was more complex. In eyes with a plateau iris configuration, the anterior convexity of the midperipheral iris may be absent or reduced (depending on the amount of relative pupil block). In the present study, we found that length of iris shadow was greater in eyes with steep iris profile and lesser in eyes with a mainly plateau iris profile.

Reproducibility is an important measure for any screening test. By using the slit lamp to standardize the direction of the light and quantitatively measure the iris shadow and corneal diameter, the oblique test was able to achieve good agreement between observers. This test also validated well against standard gonioscopy. In clinical practice, if one can develop a simple device that is able to standardize the direction of light, use a viewer with graticule or concentric circles to semiquantitatively measure the iris shadow, or even use a set of standard photographs to standardize the grading, the flashlight oblique test might be promising as an approach for screening for angle closure.

Important strengths of the study include the fact that the participants came from a random sample of the population of Liwan District of Guangzhou. The controls did not differ significantly from the population-based sample evaluated in the original study. Attempts to screen for angle closure in a community setting would involve examining populations similar to the one studied here. In addition, our masking of observers to the results of gonioscopy removed any potential bias that could be introduced in this subjective test. However, because of the
limited number of examiners involved in this study, the same
examiner collected SOFT and SSFT data. The reading of SSFT
data might have been biased by the SOFT results. However, because
the more subjective SOFT was performed before the quantita-
tive SSFT, any bias was likely small. In fact, the SSFT performed
better than the SOFT, indicating that results for the SSFT were
not unduly influenced by the SOFT results.

The ideal screening test would be relatively simple and
noninvasive and would have high sensitivity and specificity for
the detection of angle closure. Slit lamp–dependent examination
methods (such as optical pachymetry of ACD and the Van
Herick limbus chamber depth test), ultrasound-dependent methods
(such as ultrasound anterior chamber depth, ultra-
sound biomicroscopy), and other noncontact examinations
(Scheimpflug camera, anterior segment optical coherence to-
ography) have shown promise as biometric techniques in the
identification of narrow or closed angles. All these require
relatively expensive equipment or experienced examiners.
The SOFT is an equipment-free examination, and performance
can be enhanced by using standard illumination and more
accurate measurement on the iris shadow. Although the sensi-
tivity and specificity are inferior than in the report using mod-
ified Van Herick technique, it may be useful if the availability
of equipment and professionals is limited, such as for general
practitioners and others performing opportunistic screening.
However, the usefulness of the test in the hands of less expe-
ranced staff and professionals who are not ophthalmologists
must be explored. Comparison on the efficacy of Van Herick in
this population will be discussed in a separate paper.

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