Diagnostic Performance of Anterior Chamber Angle Measurements for Detecting Eyes With Narrow Angles

An Anterior Segment OCT Study

Arun Narayanaswamy, DNB; Lisandro M. Sakata, MD, PhD; Ming-Guang He, MD, PhD; David S. Friedman, MD, PhD; Yiong-Huak Chan, PhD; Raghavan Lavanya, MD; Mani Baskaran, DNB; Paul J. Foster, PhD, FRCS(Ed); Tin Aung, PhD, FRCS(Ed)

Objective: To assess the diagnostic performance of angle measurements from anterior segment optical coherence tomography (AS-OCT) images for identifying eyes with narrow angles.

Methods: We conducted a community-based cross-sectional study of individuals 50 years or older who had phakic eyes and who underwent AS-OCT imaging in the dark by a single operator and gonioscopy by an ophthalmologist masked to AS-OCT findings. An eye was considered to have narrow angles if the posterior pigmented trabecular meshwork was not visible for at least 180° on gonioscopy. Horizontal AS-OCT images were analyzed for the following measurements using customized software: angle opening distance (AOD) at 250, 500, and 750 µm from the scleral spur; trabecular-iris space area (TISA) at 500 and 750 µm; and angle recess area (ARA) at 750 µm. Areas under the receiver operating characteristic curves (AUCs) were generated for AOD, TISA, and ARA to assess the performance of these measurements in detecting eyes with narrow angles.

Results: Of 2047 individuals examined, 582 were excluded mostly because of poor image quality or inability to locate the scleral spur. Of the remaining 1465 participants, 315 (21.5%) had narrow angles on gonioscopy. Mean (SD) age was 62.7 (7.7) years, 54.1% were women, and 90.0% were Chinese. The AUCs were highest for AOD750 in the nasal (0.90 [95% confidence interval, 0.89-0.92]) and temporal (0.91 [0.90-0.93]) quadrants.

Conclusions: The AOD750 is the most useful angle measurement for identifying individuals with gonioscopic narrow angles in gradable AS-OCT images. Poor definition of the scleral spur precludes quantitative analysis in approximately 25% of AS-OCT images.


The number of people who are blind because of glaucoma is likely to reach 60.5 million worldwide by 2010. More than half of glaucoma blindness will be due to primary angle-closure glaucoma, and more than 80% of people with angle-closure disease are likely to be living in Asia. A key initiative would be to enhance the abilities of health care professionals to diagnose and detect angle closure at an early stage. Gonioscopy is the current reference standard for detecting eyes with or at risk of angle closure. Although technically a simple procedure, many subjective influences govern its interpretation, and a level of ability and expertise is required to ensure that gonioscopy findings are accurate.

Anterior segment optical coherence tomography (AS-OCT) is capable of providing objective high-resolution images of the angle, and these images can be analyzed qualitatively and quantitatively. Imaging of the angle with AS-OCT can be performed in less than a minute by a technician and does not require contact with the eye. Customized software can be used for semiautomated analysis of AS-OCT images to obtain several measurements of the anterior chamber angle, and the results of this analysis could be useful for detecting eyes at risk of angle closure. A previous community-based study by our group involving a qualitative analysis of AS-OCT images showed a suboptimal diagnostic performance for detection of narrow angles, mostly because of poor specificity values.

Author Affiliations are listed at the end of this article.
The aim of this study was to evaluate the diagnostic performance of quantitative AS-OCT angle measurements for detecting eyes with gonioscopic narrow angles.

METHODS

Subjects for this study were participants in a study evaluating the usefulness of new imaging devices for detecting narrow angles among Singaporeans attending a government-run polyclinic mostly for general medical problems. All participants were 50 years or older and were systematically sampled (every fifth patient registered at the polyclinic). Informed consent was obtained from all participants, the institutional review board of the Singapore National Eye Center approved the protocol, and the study adhered to the tenets of the Declaration of Helsinki.

After an interview about medical and ophthalmic history, each participant underwent the following examinations on the same day: visual acuity, anterior segment imaging by AS-OCT, anterior chamber depth and axial length measurements (IOL Master; Carl Zeiss Meditec Inc, Dublin, California), slitlamp biomicroscopy, Goldmann applanation tonometry, gonioscopy, and stereoscopic posterior pole (optic disc and macula) examination. Individuals were excluded if they had a history of intraocular surgery, any evidence of aphakia/pseudophakia, or penetrating trauma in the eye; previous anterior segment laser treatment; a history of glaucoma; or corneal disorders such as corneal endothelial dystrophy, corneal opacity, or pterygium, all of which could influence the quality of angle imaging by AS-OCT.

GONIOSCOPY

Gonioscopy was performed in the dark in all cases by a single examiner masked to AS-OCT findings. The examiner was a trained ophthalmologist (R.L.) with extensive experience in performing gonioscopy in a research setting. A 1-mm light beam was reduced to a very narrow slit, and the vertical beam was offset horizontally for evaluating nasal and temporal angles and maintained vertical for assessing superior and inferior angles. Static and dynamic gonioscopy was performed using a Goldmann 2-mirror lens (Haag-Streit AG, Koeniz, Switzerland) and a Sussman 4-mirror lens (Ocular Instruments Inc, Bellevue, Washington), respectively, at high magnification (×16), with the eye in the primary position of gaze. Care was taken to avoid light from falling on the pupil and to avoid inadvertent indentation during examination. In some cases, the gonioscopy lens was tilted minimally to permit a view of the angle over the convexity of the iris, avoiding ocular distortion. The angle in each quadrant was graded using the Scheie grading system according to the anatomical structures observed during gonioscopy (grade IV, Schwalbe’s line not visible; grade III, Schwalbe’s line visible; grade II, anterior trabecular meshwork visible; grade I, visible scleral spur; and grade 0, ciliary body band visible).

We used the International Society for Geographical and Epidemiological Ophthalmology glaucoma classification. Because the primary aim of the study was to screen for narrow angles in the community, we combined primary angle-closure suspect, primary angle closure, and primary angle-closure glaucoma into a single category, namely, narrow angle. An eye was defined as having a narrow angle if the posterior pigmented trabecular meshwork was not visible for at least 180° of nonindentation gonioscopy with the eye in the primary position.

ANTERIOR SEGMENT OPTICAL COHERENCE TOMOGRAPHY

Anterior segment imaging was obtained using a commercially available AS-OCT (Visante; Carl Zeiss Meditec Inc). The details of AS-OCT imaging technology have been described previously. Briefly, this technology permits image acquisition at a rate of 8 frames/s (2000 A-scans/s), with a transverse resolution of 60 µm and an axial resolution of 10 to 20 µm. Furthermore, the use of wide-field scanning optics (16 mm) and a deep axial scan range (8 mm) allows AS-OCT to image a cross section of the anterior chamber in a single image frame. After acquisition, the scanned images are processed by a customized (“dewarping”) software that compensates for index of refraction transition at the air-tear interface and the different indices in air, cornea, and aqueous humor to correct the physical dimensions of the images. Seated participants were examined by a single ophthalmologist (R.L.) who was masked to other test results before any procedure that involved contact with the eye. Three AS-OCT images of the anterior chamber angle of each eye were obtained in dark conditions using the single-scan-mode protocol: one image scanning the angle at the 3- and 9-o'clock positions (horizontal meridian; Figure 1) followed by one scanning the superior angle at 12 o'clock and one scanning the inferior angle at 6 o'clock. Imaging at the 12- and 6-o'clock positions was obtained separately to avoid possible interference of the eyelid. During the image capture, the upper eyelid was gently elevated to image the superior angle and the lower eyelid was gently pulled down by the operator to image the inferior angle, taking care to avoid inadvertent pressure on the globe.

The Zhongshan Angle Assessment Program (ZAAP; Zhongshan Ophthalmic Centre, Guangzhou, China) was used to analyze the AS-OCT images for quantitative measurements. For each image, the only observer input was to determine the location of the 2 scleral spurs. All analysis was performed by a single fellowship-trained glaucoma specialist (L.M.S.). The algorithm then automatically calculated the following angle measurements (Figure 2): angle opening distance (AOD), angle recess area (ARA), and trabecular-iris space area (TISA).

Angle opening distance was defined by Pavlin et al as the length of a line drawn from the anterior iris to the corneal endothelium, perpendicular to a line drawn along the trabecular meshwork at a given distance from the scleral spur. The AOD was calculated at 250, 300, and 750 µm from the scleral spur (AOD250, AOD300, and AOD750, respectively). The ARA and TISA were measured according to the guidelines by Ishikawa et al and Radhakrishnan et al, respectively. The ARA represents measurement of the area bordered by the anterior iris surface, corneal endothelium, and a line perpendicular to the corneal endothelium that is drawn to the iris surface from a point 750 µm anterior to the scleral spur. The TISA is a measurement that is further modified by not including the area below a line drawn from the scleral spur to the anterior iris perpendicular to the plane of the inner scleral wall. The ARA was calculated at 730 µm (ARASA750), and the TISA was calculated at 300 and 750 µm (TISASA300 and TISASA750, respectively).

Currently, the ZAAP program can analyze only AS-OCT scans imaging both angles at the same time (ie, horizontal scans imaging both nasal and temporal angles; Figure 2), and it cannot analyze AS-OCT scans imaging 1 angle only (ie, vertical scans imaging the superior angle only or the inferior angle only). Thus, the quantitative analysis of the present study evaluated only the horizontal scan.

STATISTICAL ANALYSIS

Mean values of quantitative angle measurements were compared between the group with gonioscopically open angles and the group with narrow angles. Receiver operating characteristic curve was generated for the quantitative measurements of AOD, TISA, and ARA, and the area under the receiver operating characteristic curve (AUC) was calculated to assess the performance of these measurements in detecting eyes with narrow angles.
The statistical analysis was performed using the Stata statistical package (version 9.1; StataCorp LP, College Station, Texas). Data were entered into CLINTRIAL, and reporting of the study followed the STARD guidelines. Receiver operating characteristic curves, with calculation of AUC and 95% confidence intervals (CIs), were used as an index of global test performance. Values for specificity, sensitivity, and negative and positive predictive values were calculated, with gonioscopy as the reference standard. Cutoff values of quantitative measurements with best AUCs were generated. The negative and positive predictive values were calculated by using a prevalence of angle closure of 10% from the Tanjong Pagar population-based study and also of 20% as noted in the present study.

RESULTS

A total of 2047 individuals were recruited into the study, but 582 were excluded because of an inability to locate the scleral spur (515 individuals), poor image quality (28), and software delineation errors (39). Therefore, data from 1465 participants (71.6%) were included in the analysis. Of these, 793 (54.1%) were female, and 1318 (90.0%) were Chinese (Table 1). The mean (SD) age was 62.7 (7.7) years. There were no significant differences in race, spherical equivalent refraction, intraocular pressure, or axial length, but included participants were younger \( (P < .001) \) (Table 1).

Three hundred fifteen participants (21.5%) were diagnosed as having narrow angles on gonioscopy. The mean values of AOD, ARA, and TISA for eyes with and without narrow angles were significantly different \( (P < .001) \) (Table 2).

The AUCs were highest for AOD750 in the nasal (0.90 [95% CI, 0.89-0.92]) and temporal (0.91 [0.90-0.93]) quadrants (Table 3 and Figure 3) followed by AOD500. The AUCs for TISA750 in the nasal and temporal quadrants were 0.87 (95% CI, 0.85-0.89) and 0.88 (0.86-0.89), respectively. The AUCs for ARA750 in the nasal

![Figure 1](image1.png)  
**Figure 1.** Example of an anterior segment optical coherence tomography scan depicting an eye with an open angle (A) and a closed angle (B). The scleral spurs are noted (arrows).

![Figure 2](image2.png)  
**Figure 2.** Schematic representation of areas and distances used as specifications of quantitative angle measurements by anterior segment optical coherence tomography. Areas in this image are represented at 500 µm from the scleral spur, and similar areas can be derived at 250 and 750 µm when required. AOD indicates angle opening distance; ARA, angle recess area; and TISA, trabecular-iris space area.
and temporal quadrants were 0.83 (95% CI, 0.81-0.85) and 0.84 (0.82-0.86), respectively. The highest AUCs for detecting narrow angles after assigning various cutoffs for the quantitative measurements are given in Table 4. At no cutoff value was the specificity greater than 90%. The highest AUCs were generated for AOD750 in the nasal and temporal quadrants at cutoff values of 225 and 258 µm, respectively.

**COMMENT**

In this study, AS-OCT quantitative angle measurements performed reasonably well in detecting eyes with narrow angles, with AUC values of 0.90 for AOD750 in the nasal quadrant and 0.91 for AOD750 in the temporal quadrant. However, 25.2% of our community-based study sample had to be excluded because of difficulty in determining the location of the scleral spur, a landmark that is essential for angle measurement. Thus, although quantitative AS-OCT analysis represents a promising method for detecting eyes at risk of angle closure, the difficulty in detecting the location of the scleral spur currently represents an important drawback, limiting its use for purposes of population screening.

Locating the scleral spur in an AS-OCT image depends on cues such as high pixel reflectivity in the region of the scleral spur, inward protrusion of the sclera, and a subtle change in the contour of the inner scleral margin. These cues are distorted in pixilated images when image quality is compromised or in very narrow angles in which the iris is close to the scleral wall, even when image acquisition was technically good. The limited resolution of the AS-OCT images used in this study represented the main factor precluding scleral spur identification, particularly when the quantitative analysis requires the examiner to point to the exact location of the scleral spur, which represents the anatomical reference.
point for performing all the anterior chamber measurements. Higher-resolution AS-OCT scans (eg, those obtained with the enhanced mode) may have resulted in images with better scleral spur localization, but the images acquired with this mode using the current-generation AS-OCT device are not corrected for the different indices of refraction of the air, cornea, and aqueous humor (ie, the images are not “dewarped”). Correction for these factors and advancement in existing technology may improve the rate of scleral spur identification, which in turn could improve the performance of AS-OCT.

Our group reported previously\(^1\) that subjective interpretation of OCT images was used to qualitatively assess the presence or absence of angle closure in more than 2000 individuals in whom all 4 quadrants were analyzed in each eye. This was possible even in many eyes with poor definition of the scleral spur by relying on other anatomical features of the anterior chamber, such as the angle opening distance (AOD) of 750 µm (AOD750). The area under the receiver operating characteristic curve (AUC) for AOD750 in the nasal quadrant was 0.90 (95% CI, 0.89-0.92) and in the temporal quadrant was 0.91 (95% CI, 0.90-0.93). Figure 3 shows the receiver operating characteristic curves for the detection of narrow angles using AOD750.

Table 4. Quantitative Angle Measurements for Nasal and Temporal Quadrants vs Diagnostic Statistical Measures for 10% and 20% Prevalence of Angle Closure\(^a\)

<table>
<thead>
<tr>
<th>Angle Measurement(^b)</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>PPV</th>
<th>NPV</th>
<th>AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nasal quadrant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AOD250 (\leq 138 \mu m)</td>
<td>75.6 (70.8-80.3)</td>
<td>70.6 (68.0-73.2)</td>
<td>22.2 (18.6-25.8)</td>
<td>96.3 (95.1-97.5)</td>
<td>39.1 (35.1-43.1)</td>
<td>92.0 (90.2-93.8)</td>
<td>0.73 (0.70-0.76)</td>
</tr>
<tr>
<td>AOD500 (\leq 177 \mu m)</td>
<td>85.1 (81.1-89.0)</td>
<td>76.1 (73.7-78.6)</td>
<td>28.3 (24.1-32.5)</td>
<td>97.8 (97.0-98.7)</td>
<td>47.1 (42.8-51.3)</td>
<td>95.3 (93.9-96.6)</td>
<td>0.81 (0.78-0.83)</td>
</tr>
<tr>
<td>AOD750 (\leq 225 \mu m)</td>
<td><strong>82.5 (78.3-86.7)</strong></td>
<td><strong>84.0 (81.9-86.2)</strong></td>
<td><strong>36.4 (31.3-41.6)</strong></td>
<td><strong>97.7 (96.8-98.6)</strong></td>
<td><strong>56.3 (51.6-61.0)</strong></td>
<td><strong>95.0 (93.7-96.3)</strong></td>
<td><strong>0.83 (0.81-0.86)</strong></td>
</tr>
<tr>
<td>TISA500 (\leq 76 \mu m^2)</td>
<td>73.3 (68.4-78.2)</td>
<td>75.2 (72.7-77.7)</td>
<td>24.6 (20.6-28.6)</td>
<td>96.1 (95.0-97.3)</td>
<td>42.4 (38.1-46.7)</td>
<td>91.8 (90.0-93.5)</td>
<td>0.74 (0.71-0.77)</td>
</tr>
<tr>
<td>TISA750 (\leq 134 \mu m^2)</td>
<td>80.3 (75.9-84.7)</td>
<td>77.5 (73.1-79.9)</td>
<td>28.4 (24.1-32.8)</td>
<td>97.2 (96.3-98.2)</td>
<td>47.2 (42.5-51.8)</td>
<td>94.0 (92.5-95.5)</td>
<td>0.76 (0.73-0.78)</td>
</tr>
<tr>
<td>ARA750 (\leq 154 \mu m^2)</td>
<td>74.0 (69.1-78.8)</td>
<td>75.8 (73.3-78.3)</td>
<td>25.2 (21.1-29.3)</td>
<td>96.2 (95.0-97.4)</td>
<td>43.2 (38.9-47.5)</td>
<td>92.0 (90.3-93.7)</td>
<td>0.75 (0.72-0.78)</td>
</tr>
<tr>
<td><strong>Temporal quadrant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AOD250 (\leq 144 \mu m)</td>
<td>77.1 (72.5-81.8)</td>
<td>68.2 (65.6-70.9)</td>
<td>21.2 (17.7-24.7)</td>
<td>96.4 (95.2-97.6)</td>
<td>37.7 (33.8-41.6)</td>
<td>92.2 (90.4-94.0)</td>
<td>0.73 (0.70-0.76)</td>
</tr>
<tr>
<td>AOD500 (\leq 191 \mu m)</td>
<td>88.9 (85.4-92.3)</td>
<td>74.6 (72.1-77.1)</td>
<td>27.9 (23.8-32.0)</td>
<td>98.3 (97.5-99.1)</td>
<td>46.6 (42.5-50.7)</td>
<td>96.4 (95.1-97.6)</td>
<td>0.82 (0.79-0.84)</td>
</tr>
<tr>
<td>AOD750 (\leq 258 \mu m)</td>
<td><strong>90.2 (86.9-93.4)</strong></td>
<td><strong>77.4 (74.9-79.8)</strong></td>
<td><strong>30.6 (26.2-34.9)</strong></td>
<td><strong>98.6 (97.8-99.3)</strong></td>
<td><strong>49.9 (45.6-54.2)</strong></td>
<td><strong>96.9 (95.8-98.0)</strong></td>
<td><strong>0.84 (0.81-0.86)</strong></td>
</tr>
<tr>
<td>TISA500 (\leq 103 \mu m^2)</td>
<td>88.2 (84.7-91.8)</td>
<td>59.1 (56.3-62.0)</td>
<td>19.3 (16.3-22.3)</td>
<td>97.7 (96.7-98.8)</td>
<td>35.0 (31.6-38.5)</td>
<td>95.2 (93.6-96.7)</td>
<td>0.74 (0.71-0.76)</td>
</tr>
<tr>
<td>TISA750 (\leq 151 \mu m^2)</td>
<td>83.5 (79.4-87.6)</td>
<td>76.7 (74.3-79.2)</td>
<td>28.4 (24.1-32.6)</td>
<td>97.6 (96.7-98.5)</td>
<td>47.3 (43.0-51.6)</td>
<td>94.8 (93.4-96.2)</td>
<td>0.80 (0.77-0.83)</td>
</tr>
<tr>
<td>ARA750 (\leq 191 \mu m^2)</td>
<td>84.1 (80.1-88.2)</td>
<td>69.2 (66.5-71.9)</td>
<td>23.2 (19.6-26.8)</td>
<td>97.4 (96.4-98.5)</td>
<td>40.6 (36.7-44.4)</td>
<td>94.5 (93.0-96.0)</td>
<td>0.77 (0.74-0.80)</td>
</tr>
</tbody>
</table>

Abbreviations: AOD, angle opening distance; ARA, angle recess area; AUC, area under the receiver operating characteristic curve; NPV, negative predictive value; PPV, positive predictive value; TISA, trabecular-iris space area.

\(^a\) The 95% confidence intervals are given in parentheses. Boldface type signifies measurements with a high AUC.

\(^b\) Numbers (250, 500, and 750) indicate the distance in micrometers from the scleral spur.
location of iris insertion. However, the diagnostic performance was not good (AUC of 0.76), with a reasonable sensitivity (84%) but poor specificity (68%) for detecting eyes with narrow angles on gonioscopy. This poor specificity was mainly the result of significantly more closed angles in the superior and inferior quadrants compared with gonioscopy.

Currently, the ZAAP software can analyze only AS-OCT scans imaging the entire anterior segment of the eye that include both angles in same image. This study acquired horizontal images simultaneously, but the superior and inferior angles were imaged separately to avoid interference of the eyelid or accidental indentation when moving the eyelids out of way at the same time. Based on the previous report from our group, there was iridocorneal contact at the superior and inferior images in approximately 40% of the eyes.19 Thus, had we included the superior and inferior angles, it is likely that an even higher proportion of eyes would have had closed angles with AS-OCT, further decreasing the specificity of the images compared with gonioscopy as the reference standard examination.

It is important to acknowledge that AOD750 is influenced by the iris contour and that these values used in isolation could result in a false interpretation of angle status. The measurements of ARA and TISA were proposed by Ishikawa et al17 and Radhakrishnan et al16 to overcome this potential error; however, in the present study, ARA750 and TISA750 had relatively low AUCs (ARA750: nasal/temporal AUCs, 0.83/0.84, and TISA750: nasal/temporal AUCs, 0.87/0.88). Of note, there were 3 of 315 eyes with gonioscopically narrow angles that had a wide AOD750 (ie, >380 µm, the mean AOD750 for quadrants with gonioscopically open angles). The reason for this discrepancy is that gonioscopic classification of narrow angles was based on closure in any 2 quadrants, whereas AOD750 was for nasal and temporal quadrants only. Previous studies have found that, with gonioscopy, superior quadrants are narrower compared with nasal and temporal quadrants in most eyes,20 and Kunimatsu et al,21 in their study using ultrasound biomicroscopy, have also noted that the angles in the superior and inferior quadrants are narrower compared with the nasal and temporal quadrants. Our group previously reported a higher likelihood of finding closed angles with AS-OCT in the superior and inferior quadrants,10 and these eyes may have narrow (but open) angle width in the nasal and temporal quadrants.22 Thus, in some eyes classified as having narrow angles, the AOD750 may be wide. In contrast to the findings reported herein, a clinic-based study using a prototype AS-OCT device on a small sample of 31 eyes reported the highest AUCs for AOD500 (0.98) and TISA750 (0.96).10 Those authors did not measure the AOD750 and instead used ARA750, which they noted had a high AUC of 0.96.

The present study is community based, reducing the selection bias seen in clinic-based studies. The diagnostic performance of the AS-OCT observed in this study may better reflect its performance in a real-life population-based setting. Unfortunately, a large proportion of participants had images that could not be quantitatively evaluated because of poor definition of the scleral spur.

Some limitations of the study were that the included participants tended to be younger and women and also tended to have a shallower anterior chamber depth. Apart from these limitations, we used a single cross section of the angle and do not know whether the performance of AS-OCT would be better if we performed multiple scans in different meridians. Performing a single scan may lead to error if there was isolated peripheral anterior synchiae in the area scanned. Another potential limitation to the interpretation of these results is that this study used gonioscopic categorization of the angle as the reference standard. However, gonioscopy is a subjective test, and subjective angle evaluation may also be prone to misclassification. For example, there could be inadvertent indentation during gonioscopy, resulting in the opening of closed angles. The lack of correlation between AS-OCT and gonioscopy could also result from the fact that AS-OCT can be performed in a completely dark room, whereas gonioscopy still requires a minimum amount of light. Diagnostic performance may also have been different if all images had been gradable.

In summary, quantitative analysis of AS-OCT images remains a promising approach for detecting eyes at risk of angle closure. The AUC value of 0.90 for AOD750 renders this as the measurement with the best discriminative ability for detecting narrow angles. Inability to define the scleral spur remains a major drawback, but future improvement in technology may be able to overcome this limitation.23

Submitted for Publication: October 6, 2009; final revision received November 23, 2009; accepted January 8, 2010.

Author Affiliations: Glaucoma Services (Dr Aung), Singapore National Eye Centre, and Singapore Eye Research Institute (Drs Narayanaswamy, Lavanya, and Baskaran), and Department of Biostatistics, Yong Loo Lin School of Medicine, National University of Singapore (Drs Chan and Aung), Singapore; Glaucoma Services, Universidade Federal do Paraná, Curitiba, Brazil (Dr Sakata); Department of Preventive Ophthalmology, Zhongshan Ophthalmic Centre, Guangzhou, China (Dr He); Department of Ophthalmology, Wilmer Eye Institute and Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland (Dr Friedman); and Glaucoma Services, National Biomedical Research Centre for Ophthalmology, UCL Institute of Ophthalmology and Moorfields Eye Hospital, London, United Kingdom (Dr Foster).

Correspondence: Tin Aung, PhD, FRCS(Ed), Glaucoma Services, Singapore National Eye Centre, 11 Third Hospital Ave, Singapore 168751 (tin11@pacific.net.sg).

Author Contributions: Drs Narayanaswamy and Sakata are considered joint first authors.

Financial Disclosure: Dr Friedman reports having been a paid consultant to Carl Zeiss Meditec Inc, Dr Foster reports receiving honoraria and travel support from Carl Zeiss Meditec Inc, and Dr Aung reports receiving research funding, honoraria, and travel support from Carl Zeiss Meditec Inc.

Funding/Support: This study was supported in part by grants from Singhealth, Singapore; the National Medical Research Council, Singapore; and the National Re-
If we take the escape of vitreous occurring during this operation as being about 5 to 6 per cent in the hands of skilled operators, and allow that one case out of 98 in which this accident happens develops subsequent disease of the fundus, we arrive at the conclusion that loss of vitreous in this operation, provided the eye recovers from its immediate effects, is not the serious complication which it at first sight appears. It is interesting to note that this is the opinion arrived at by Major Smith some years ago from a general experience of these cases, apart from any definite research in this subject. It is especially interesting to note that detachment of the retina, the condition so generally feared as liable to occur after escape of the vitreous, did not occur in a single case.


Note: Major Henry Smith (1859-1948), a general surgeon in the British Indian Army, operated on more patients for cataract than had ever been done before. By 1921, his experience was more than 50,000 cases.