## Title

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# Anterior segment optical coherence tomography for detection of narrow angles: a community-based diagnostic accuracy study

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## Abstract

**Purpose:** To assess the diagnostic accuracy of anterior segment optical coherence tomography (AS-OCT) screening for detecting gonioscopically narrow angles.

**Design:** Population-based cross-sectional study.

**Participants:** A stratified random sample of individuals aged 60 years or older, selected from a door-to-door census performed in low-lying Nepal.

**Testing:** Participants underwent AS-OCT, posterior segment OCT, and intraocular pressure (IOP) testing in the community. Those meeting referral criteria in either eye were invited to have a comprehensive eye examination including gonioscopy. Referral criteria included the most extreme 2.5% of AS-OCT measurements; retinal OCT results suggestive of glaucomatous optic neuropathy, diabetic retinopathy, or age-related macular degeneration; and elevated IOP.

**Main Outcome Measures:** Sensitivity and specificity of 5 semi-automated AS-OCT parameters relative to gonioscopically narrow angles, defined as the absence of visible trabecular meshwork for ≥ 180° on nonindentation gonioscopy.

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**Supplemental material:** This article contains additional online-only material. The following should appear online-only: Figures 2 and 3 and Table 1.

**Results:** Of 17,656 people aged ≥ 60 years enumerated from 102 communities, 12,633 (71.6%) presented for AS-OCT testing. Referral was recommended for 697 participants based on AS-OCT criteria and 2,419 participants based on other criteria, of which 858 had gonioscopy performed by a glaucoma specialist. Each of the 5 AS-OCT parameters offered good diagnostic information for predicting eyes with gonioscopically narrow angles, with areas under the Receiver Operating Characteristics (ROC) curve ranging from 0.85 to 0.89. The angle opening distance at 750 μm from the scleral spur (AOD750) provided the most diagnostic information, providing an optimal sensitivity of 87% (95%CI 75–96%) and specificity of 77% (71–83%) at a cutpoint of 367 μm, and a sensitivity of 65% (95%CI 54–74%) when specificity was constrained to 90% (cutpoint 283 μm).

**Conclusions:** On AS-OCT, the AOD750 parameter detected approximately two-thirds of cases of gonioscopically narrow angles when test specificity was set to 90%. While such a sensitivity may not be sufficient when screening solely for narrow angles, AS-OCT requires little additional effort if posterior segment OCT is already being performed and thus could provide incremental benefit when performing OCT-based screening.

### Keywords

glaucoma; angle-closure; anterior eye segment; tomography; optical; sensitivity and specificity

## INTRODUCTION

Angle closure glaucoma accounts for approximately half of glaucoma blindness worldwide.[1] Diagnosis requires an examination of the anterior chamber angle, typically with dynamic gonioscopy performed by an ophthalmologist.[2] Although gonioscopy is still the gold standard method, it has several disadvantages.[3] Gonioscopy must be done in a dark eye clinic room by a knowledgeable and experienced examiner. The goniolens must contact the patient's cornea at the appropriate angle and pressure, a relatively challenging technique with a steep learning curve. The technique is inherently subjective, with moderate inter-rater agreement even among trained glaucoma specialists.[4–6] Perhaps due to the complexity of the technique, gonioscopy is frequently omitted from the routine eye examination, even for patients with glaucoma or glaucoma suspects.[7]

Anterior segment imaging with anterior segment optical coherence tomography (AS-OCT) is a non-contact method that is more objective and reproducible than gonioscopy, and does not require an experienced examiner.[8–10] Several numeric parameters can be assessed from an AS-OCT scan to provide an estimate of the width of the angle opening. However, it is unclear what cutoff should be used to consider an angle to be narrow despite numerous studies on the topic.[11–18] This is especially true given the dearth of population-based studies that have assessed the diagnostic accuracy of AS-OCT for narrow angles. Many prior diagnostic accuracy studies have been case-control studies, which are subject to bias.[19, 20]

The Village Integrated Eye Worker Trial II (VIEW II) is a cluster-randomized trial in which communities in low-lying Nepal are randomized to an OCT screening intervention or no intervention.[21] In intervention communities all residents aged 60 years or older are offered OCT and those meeting pre-specified criteria are referred to the local eye hospital for a comprehensive eye examination including gonioscopy. The trial design thus offered an opportunity to assess the accuracy of AS-OCT for diagnosis of gonioscopically narrow angles in a population-based sample. Our objective in the present study was to determine which AS-OCT parameters were best for predicting narrow angles, and to determine the optimal thresholds for each parameter.

# METHODS

## Ethics.

The study was approved by ethical review boards at the University of California, San Francisco, and the Nepal Health Research Council. Written informed consent was obtained from all participants. The research adhered to the tenets of the Declaration of Helsinki.

## Study Design.

The Village-Integrated Eye Worker Trial II (VIEW II) is an ongoing NIH-funded cluster-randomized trial that takes place in peri-urban communities in the Chitwan and Nawalpur districts in Nepal (clinicaltrials.gov NCT03752840).[21] In the study, a population census of all households is performed in a contiguous geographic area surrounding Bharatpur, Nepal, and then communities are randomized to either a screening intervention or no intervention. All individuals ≥ 60 years of age in the intervention communities are invited to a central location in the community to receive a screening examination, and those meeting pre-specified referral criteria are sent to Bharatpur Eye Hospital for a standardized comprehensive eye examination, which includes gonioscopy.

## Eligibility.

The underlying study is a community-randomized trial. Communities are eligible if they lie within the catchment area of Bharatpur Eye Hospital and are accessible to a four-wheel drive vehicle. The present analysis includes participants from 102 study evaluation units that had been enrolled in the trial from January 1, 2020 to September 30, 2021 and were randomized to the screening intervention (Figure 1). All community members aged 60 years or older in the intervention communities were eligible to participate in the screening visit.

## Index tests.

Four teams were sent into the community to perform screening tests, with each team consisting of 2 ophthalmic assistants. Screening tests were performed in a dimmed room of a building in the community. The screening test of interest for the present study was a single HD Angle scan from the Cirrus 4000 AS-OCT (Carl Zeiss Meditec, Inc., Dublin, CA), captured from the temporal limbus of each eye in dim lighting by a trained ophthalmic assistant according to the manufacturer's recommendations. An external lens is not used to capture the HD Angle scan. Although scans of other angle locations (e.g., superior, inferior, nasal) would have provided additional information, this would have reduced the feasibility of performing AS-OCT as part of a large communitywide screening, and thus only a single temporal scan was captured. The Cirrus 4000 is a spectral domain OCT device with an 840 nm superluminescent diode light source. The HD Angle protocol generates a single speckle-reduced raster with transverse resolution <20 μm at a depth of 2.9 mm. The scan is 6.0 mm in length and generated from 20 B-scans, each of which is composed of

1024 A scans. The Zeiss device includes proprietary software to assist with semi-automated measurement of several anterior segment indices, including the angle opening distances at 500 μm and 750 μm from the scleral spur (AOD500 and AOD750, respectively), the trabecular iris space area at 500 μm and 750 μm from the scleral spur (TISA500 and TISA750, respectively), and the scleral spur angle (SSA). The ophthalmic assistant who performed the scan used the software immediately after scan capture to measure each of the parameters, following the manufacturer's recommendations. The software provides a trapezoidal caliper to measure the angle anatomy. The first and most important step was identification of the scleral spur, which was then followed by placement of the trapezoidal caliper along the corneal endothelial and iris borders.

### Referral criteria.

At the start of the study, normative data on each of the AS-OCT parameters were lacking. Thus, after enrolling 5,000 participants, the most extreme 2.5th percentile observed to that point was used as a referral threshold for each AS-OCT metric: AOD500 < 170 μm, AOD750 < 250 μm, TISA500 < 0.07 $mm^2$, TISA750 < 0.13 $mm^2$, and SSA <18°. A participant meeting the criteria for any of the 5 parameters was referred. These referral criteria were chosen in an attempt to identify cases of angle closure that were most likely to progress to glaucoma while not over-burdening the referral eye hospital. The 2.5% threshold was deemed reasonable given an estimated 1.2% prevalence of primary angle closure glaucoma among people ≥ 60 years in Nepal, as well as prior studies that have observed that those with the narrowest angles are most likely to progress to angle closure glaucoma.[22–25] The screening evaluation also included optic nerve and macula OCTs as well as intraocular pressure testing using an iCare ic100 rebound tonometer (iCare Finland Oy, Vantaa, Finland). Participants were referred if the optic nerve scan of either eye had abnormal superior or inferior average thickness on the automatic retinal nerve fiber layer summary; if the macula scan of either eye had evidence of intraretinal hemorrhages, macular edema, many intermediate or ≥1 large druse, geographic atrophy, choroidal neovascularization, or another vision-threatening retinal condition; or if the intraocular pressure in either eye was ≥ 23 mm Hg. The IOP threshold was arbitrary, but selected in an attempt to minimize false positive referrals to the eye hospital.

### Reference test.

Referred participants were given a referral slip for a comprehensive eye examination at Bharatpur Eye Hospital. Hospital fees were covered by the study. The comprehensive examination included dynamic gonioscopy by a fellowship-trained glaucoma specialist (RKS), performed at high magnification (×16) in a dark room using a Volk G-4 four-mirror lens with handle. The Scheie grading system was used to document the visible angle structures (i.e., ciliary body, scleral spur, anterior trabecular meshwork, and Schwalbe's line) visible in each quadrant, both without and with indentation.[26] A gonioscopic narrow angle was defined for this study as the absence of a visible trabecular meshwork for ≥ 180° on nonindentation gonioscopy when the eye was in primary position. The ophthalmologist performing gonioscopy completed a 1-year glaucoma fellowship in 2019 and had a busy glaucoma practice, seeing approximately 600 glaucoma patients per month during the study period. The gonioscopist was masked to the results of the community-based screening tests.

### Statistics.

Eyes in which the angle could not successfully be imaged or in which the angle metrics could not be estimated with the manufacturer's software were excluded from analyses. The main analysis included only right eyes in order to account for the non-independence of two eyes from the same person. Receiver Operating Characteristics (ROC) curves were made for each of the five AS-OCT parameters, judged relative to a reference standard of gonioscopically narrow angles. The optimal thresholds for each AS-OCT parameter were defined in two ways: first, as the cutpoint that maximized the Youden Index, and second, as the cutpoint that provided 90% specificity. This latter cutpoint, while arbitrary, was analyzed because the study was performed under the auspices of a screening program, and a test with low specificity and consequently a high false positive rate could quickly overburden the health system. Simple calculations of optimal cutpoints are sample-specific, and lead to overestimates of diagnostic accuracy that cannot be generalized to other populations. Various techniques exist to better estimate thresholds (e.g., splitting data into training/test sets, k-fold cross-validation, bootstrapping). Here, thresholds were determined by aggregating bootstrap results of multiple models, using the cutpointr package in R.[27] The sensitivity and specificity of the thresholds were calculated from the aggregate of those observations that were left out of each bootstrap sample (i.e., the "out-of-bag" observations) in order to provide a more robust estimate of diagnostic performance outside this specific study population. Classification and regression tree (CART) analysis was performed to investigate if combinations of AS-OCT parameters would have greater diagnostic accuracy; these analyses maintained the proportion of gonioscopically narrow angles of the study population in the test and training sets, used a tree depth of 3, and explored the impact of varying the fraction of observations used in the test set.

## RESULTS

A total of 17,656 people aged ≥ 60 years from 102 intervention communities were enumerated in the door-to-door census. Of these, 12,633 (71.6%) presented for AS-OCT testing. Of 24,948 total eyes tested, 22,779 (91.3%) had an image captured with high enough quality that the semi-automated software could be used to determine the AS-OCT parameters. Referral was recommended for 697 participants based on AS-OCT criteria and 2,419 participants based on other criteria. Of these, 1,212 people attended their referral visit and 858 received gonioscopy in at least one eye at the referral visit. The reason for not receiving gonioscopy at the referral visit was unavailability of the glaucoma specialist. The mean age of the population receiving gonioscopy was 70 years (range 60–94 years; standard deviation [SD] 7.1), and 46.4% were female. The age and sex distribution of the censused population, screened population, and gonioscopy population were similar, but those receiving gonioscopy were slightly more likely to be male, and to have had cataract surgery (Table S1, available at https://www.ophthalmologyglaucoma.org). The distribution of AS-OCT parameter values was similar in the screened population and gonioscopy population, both for the group that met and the group that did not meet the AS-OCT referral criteria (Figure S2, available at https://www.ophthalmologyglaucoma.org).

Table 2 summarizes the age- and sex-stratified mean and standard deviation for each of the AS-OCT angle parameters for the 11,528 screened individuals who received a valid AS-OCT scan of their right eye. When stratified by age and sex, mean measurements for each of the five angle indices were greater across increasing age categories, and higher in men. When stratified by age and cataract surgery status, mean measurements for each of the five angle indices were greater across increasing age categories, and higher among those who had cataract surgery. Test results were generally correlated with each other, with the highest correlation between AOD500 and SSA (Spearman's correlation coefficient, $\rho = 0.99$) and the lowest correlation between AOD750 and TISA500 ($\rho = 0.86$) (Figure S3, available at https://www.ophthalmologyglaucoma.org). To assess the repeatability of the semi-automated angle measurements, a random subset of 809 scans was assessed by an independent, masked grader. Inter-rater reliability was relatively high, ranging from 0.79 (95%CI 0.76–0.82) for TISA500 to 0.88 (95%CI 0.86–0.89) for AOD750.

Of the 833 right eyes with valid OCT data receiving gonioscopy on the referral examination, 135 were classified as having narrow angles. Based on this reference standard, ROC curve analysis found that the 5 parameters provided similar diagnostic accuracy, with areas under the curve (AUCs) ranging from 0.85 to 0.89 (Table 3). The AOD750 provided the most diagnostic information, with an AUC of 0.89 (95%CI 0.87 to 0.92). The AUC of AOD750 was significantly greater than that of TISA500 (P=0.0005), AOD500 (P=0.01), and SSA (P=0.02), but not TISA750 (P=0.10). When using the optimal AOD750 threshold based on the Youden index (cutpoint = 367 μm), sensitivity was 87% (95%CI 75–96) and specificity was 77% (95%CI 71–83%). When the AOD750 specificity was constrained to 90% (cutpoint = 283 μm), then the sensitivity was 65% (95%CI 54–74). CART analysis failed to detect any combinations of parameters that increased accuracy.

As shown in Figure 4, participants with abnormal AS-OCT results in both eyes were more likely to have narrow angles compared with participants with an abnormal result in only one eye. For example, of 213 participants with complete data for both eyes and an abnormal AOD750 result, 50 of 130 (38%) participants with an abnormal AOD750 measurement in a single eye were found to have narrow angles in either eye, compared with 59 of 83 (71%) participants with abnormal AOD750 measurements in both eyes (P<0.001). The positive predictive value and specificity of the test could thus be improved by referring only those cases with abnornal AS-OCT results in both eyes—although this would also result in lowering the sensitivity in half, from approximately 80% to 40% (Figure 4). The vast majority of participants found to have narrow angles on gonioscopy had bilateral involvement, regardless of whether the participant had an abnormal test in one or both eyes. For example, of the 50 participants with an abnormal AOD750 in a single eye and narrow angles on gonioscopy, 42 (84%) were diagnosed with bilateral narrow angles, and of the 59 participants with abnormal AOD750 in both eyes and narrow angles on gonioscopy, 55 (93%) were diagnosed with bilateral narrow angles. Results for other parameters were similar (Figure 4).

## DISCUSSION

This study found that while the 5 tested AS-OCT parameters provided similar amounts of diagnostic information for the diagnosis of gonioscopically narrow angles, AOD750 was slightly better than the other parameters, with a sensitivity of 65% when the cutpoint was set to achieve a specificity of 90%. Inter-rater reliability for the various AS-OCT parameters was moderate. Approximately 70% of participants with abnormal AS-OCT results in both eyes had gonioscopically narrow angles, compared to 40% of those with abnormal AS-OCT results in only one of the eyes.

Consistent with prior reports, the mean values for each of the AS-OCT parameters were higher in men.[28, 29] AS-OCT parameters in the present study were also higher for older age groups. Although the cross-sectional nature of the present study precludes assessment of changes over time, these results suggest that the anterior chamber angle parameters may increase with age in this study population. In contrast, several cross-sectional and longitudinal studies from East Asia have found a reduction in anterior chamber distance with age.[28, 30–34] The reasons behind the discrepant findings are not clear. We hypothesized that differences in the prevalence of cataract surgery might have played a role given post-operative widening of the anterior chamber angle, but we found similar trends when analyzing eyes with and without prior cataract surgery (Table 2).[35] Alternatively, the differences between this study and prior reports could be due to differences in the ocular anatomy of the underlying study populations or differences in the way the study populations were sampled. Additional longitudinal population-based studies of AS-OCT in diverse geographic settings would be helpful for better characterizing the natural history of AS-OCT parameters over time.

The present study is consistent with several previous studies that have found AOD750 to be among the most important predictors of gonioscopically narrow angles. A clinic-based retrospective study of a time-domain OCT with manual estimation of angle parameters found the AOD750 to have the highest correlation with gonioscopy.[13] A clinic-based study from Singapore that used time-domain OCT and custom-built software to measure angle parameters found the AOD750 of the temporal angle to have the highest AUC for classification of narrow angles, with an AUC of 0.91.[14] A retrospective clinic-based study of a swept-source OCT found the temporal AOD750 to have an AUC of 0.97.[17] The optimal thresholds for classifying narrow angles in this study population were in a similar range of values as have been found in prior reports, although with some variability between studies (Table 4). The specific threshold in a given population may depend on multiple factors, including age and race as well as the device and software used.

This study calculated two sets of cutpoints for each test. The first cutpoint optimized the sensitivity and specificity, and the second cutpoint constrained the specificity to 90%. We arbitrarily chose a 90% specificity, although even this level of specificity would result in a large fraction of false positive tests given the low prevalence of narrow angles in the general population. Moreover, at this cutpoint even the best parameter, AOD750, detected only 65% of cases—a lower diagnostic performance than has been achieved in studies using alternative methods such as deep learning.[36–38] Our attempts to combine multiple parameters did not provide higher levels of accuracy. The level of sensitivity observed in this study may be too low to support widespread use of these particular AS-OCT thresholds in a standalone screening program, especially since the clinical benefit of detecting narrow angles is not clear. Eyes with narrow angles have a relatively low rate of progression to primary angle closure, and thus the absolute benefit of laser peripheral iridotomy to prevent primary angle closure is small.[39] Longitudinal studies have found narrower angle parameters on AS-OCT to be more likely to progress to subsequent primary angle closure, although specific thresholds are unclear.[25, 40, 41] Yet it is worth pointing out that AS-OCT screening would almost certainly be done as an accompaniment to posterior segment OCT imaging. In this broader context, it may make sense to include AS-OCT in the overall package of screening examinations, since a considerable number of cases of narrow angles could be detected with minimal incremental cost.

Adequate quality scans were captured in 91% of participants in this study. Previous studies using time-domain OCTs have often reported a lower proportion of adequate-quality scans.[14, 42] The spectral domain OCT used in the present study produces higher-resolution images, which may have resulted in higher quality scans and easier determination of the scleral spur landmark.[43] This is consistent with a prior study of spectral domain OCT, which captured adequate-quality images in 88% of eyes.[15] The relatively high proportion of good quality scans supports the use of AS-OCT for evaluation of the anterior chamber angle.

This study has limitations. The population receiving gonioscopy may not have been completely representative of the overall population since not all participants meeting the AS-OCT referral criteria presented for gonioscopy, and because participants not meeting AS-OCT referral criteria were referred only if they met one of the other referral criteria (i.e., posterior segment OCT or IOP). However, we found no evidence that the distribution of AS-OCT parameter values was different between the overall population and the gonioscopy population—either for those referred or not referred based on AS-OCT. The reference standard gonioscopic examination was performed by a single ophthalmologist, and is subjective. Assessment of the validity and reproducibility of the gonioscopic observations was difficult due to logistical challenges at the busy eye hospital as well as the scarcity of glaucoma specialists in Bharatpur who might have performed a repeat gonioscopic examination. Only a single temporal AS-OCT scan was captured of each eye, but the reference standard was based on gonioscopy of the entire angle. Previous studies have found that the accuracy of various AS-OCT parameters for predicting narrow angles may depend on the location of the scan (e.g., nasal, temporal, inferior, or superior).[17] The change in refraction at the air-cornea interface causes distortion of the AS-OCT images, affecting measurements of angle structures. The HD Angle software adjusts the images to account for refraction of the corneal surface, but it is possible that the manufacturer's correction parameter could induce some bias in measurements. There has been some prior research showing good agreement between measurements from the Cirrus AS-OCT with other OCT devices such as the Visante, but little work has been done to specifically compare measurements using the manufacturer's semi-automated HD Angle software to those of other devices.[44] The study was performed with a specific AS-OCT device and its built-in software; observed values may have differed had a different device or software been used. Finally, the study was performed in Nepal and may not be generalizable to other populations, especially given other studies that have found AS-OCT parameters to differ based on race/ethnicity.[45]

In summary, this population-based study provided an opportunity to measure normative data regarding the anterior chamber angle using AS-OCT. In contrast to studies from East Asia, anterior angle parameters appeared to widen with advancing age in this Nepalese population. AOD750 had the best discriminative ability for classifying gonioscopically narrow angles, albeit with modest sensitivity when the specificity was constrained to 90%. The clinical utility of diagnosing gonioscopically narrow angles remains unclear given previous studies that have shown that the majority of eyes with narrow angles do not progress to vision-threatening disease. Longitudinal diagnostic accuracy studies in diverse populations would be helpful to determine the utility of AS-OCT for identifying eyes most likely to progress to angle closure.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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## Abbreviations:

| | |
|---|---|
| **AS-OCT** | anterior segment optical coherence tomography |
| **AOD** | angle opening distance |
| **AUC** | area under the curve |
| **LPI** | laser peripheral iridotomy |
| **OD** | right eye |
| **OS** | left eye |
| **ROC** | Receiver Operating Characteristics |
| **TISA** | trabecular iris space area |
| **VIEW II** | Village-Integrated Eye Worker Trial II |

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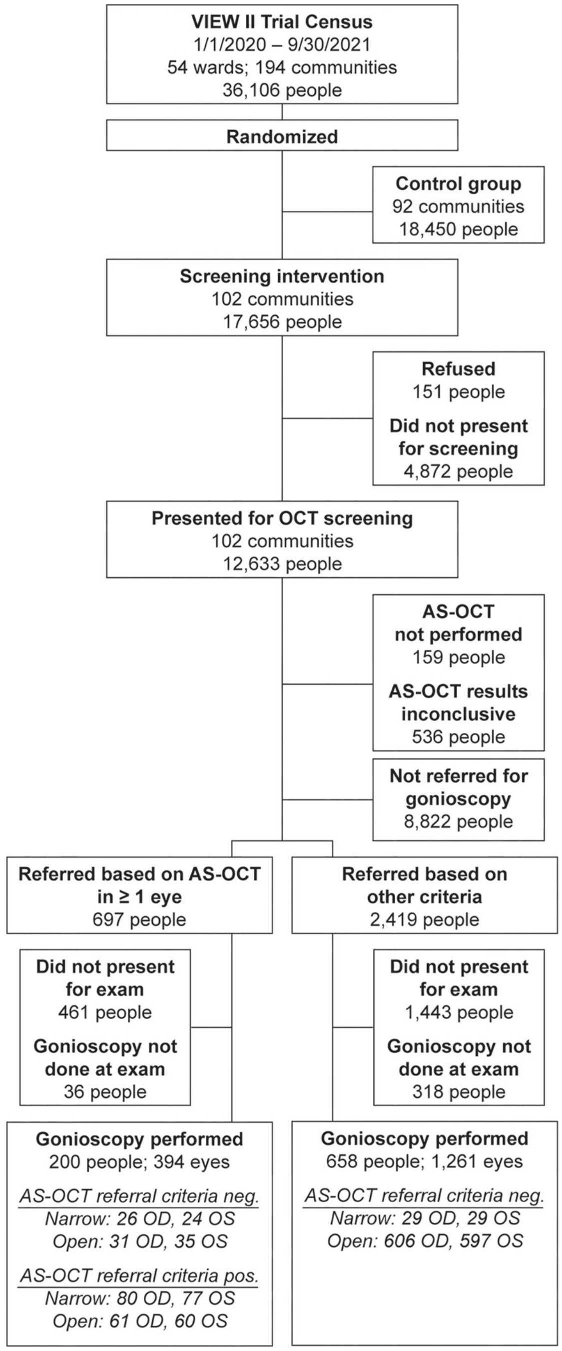


**Figure 1. Study flow.**

OD = right eye; OS = left eye.

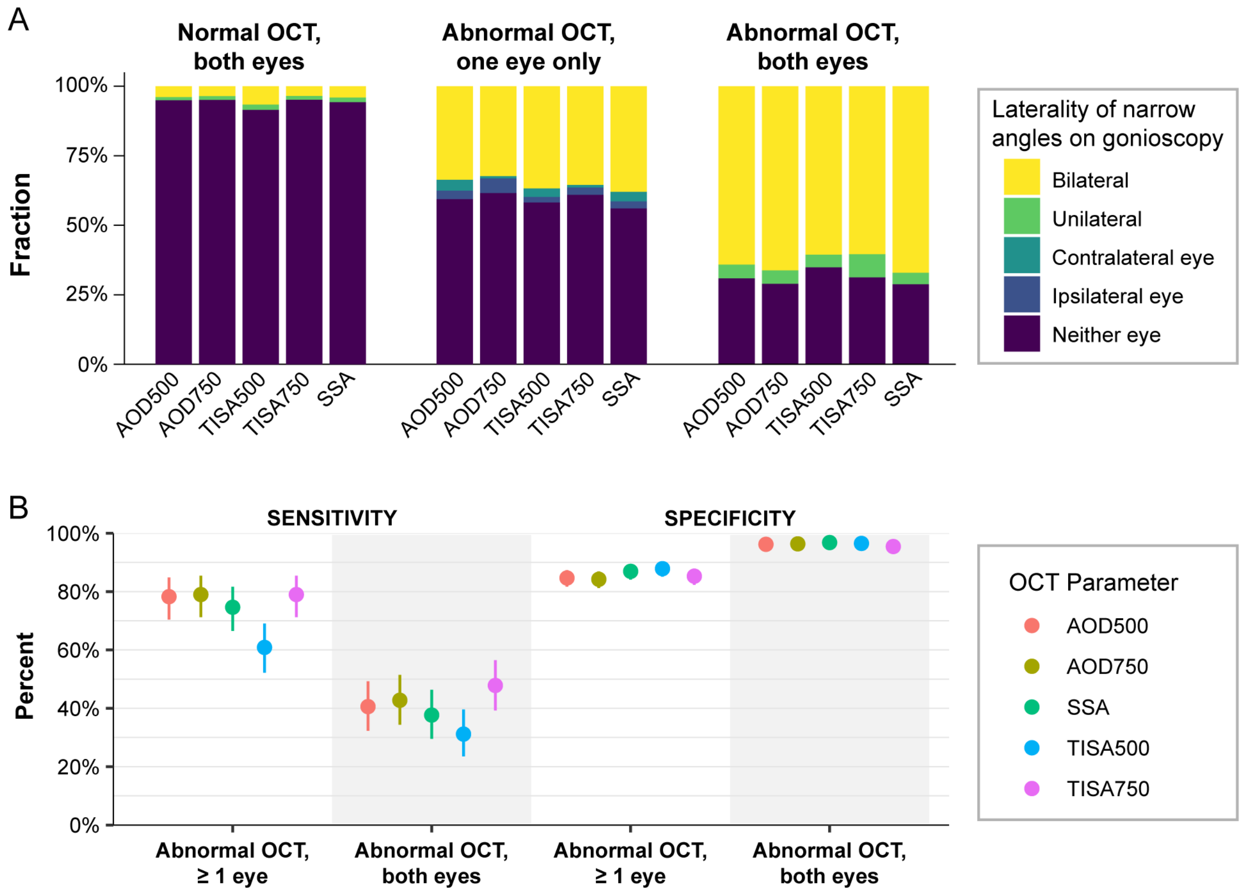


**Figure 4. Relationship between laterality of AS-OCT test results and gonioscopy results.**

Panel A shows the positive predictive value of abnormal anterior segment optical coherence tomography results, stratified by laterality of the abnormal test result. Bars depict the proportion of people who subsequently were found to have narrow angles on gonioscopy. Results are grouped by laterality of the test result (i.e., an abnormal result in neither eye, only one eye, or both eyes), and bars are shaded according to the laterality of narrow angles on gonioscopy. The cutpoint that provided 90% specificity was used to define an abnormal test result, using data from both eyes. The reference standard (i.e., narrow angles) was defined as the absence of a visible trabecular meshwork for ≥ 180° on nonindentation gonioscopy. Panel B shows the person-level sensitivity and specificity of each index test for two scenarios: (i) when an abnormal test was defined as either eye meeting the threshold, and (ii) when an abnormal test was defined as both eyes meeting the threshold (in each case using the single-eye threshold that constrained specificity to 90%).

**Table 2.**

Mean angle parameters in right eyes.

| Group | n | Mean (SD) | | | | |
|---|---|---|---|---|---|---|
| | | AOD500, µm | AOD750, µm | TISA500, mm$^2$ | TISA750, mm$^2$ | SSA, ° |
| Sex | | | | | | |
| Female | | | | | | |
| 60–64y | 1788 | 360 (159) | 491 (218) | 0.14 (0.05) | 0.23 (0.09) | 34.1 (10.7) |
| 65–69y | 1480 | 378 (184) | 507 (234) | 0.14 (0.06) | 0.24 (0.10) | 35.1 (11.4) |
| 70–74y | 1198 | 405 (191) | 549 (249) | 0.15 (0.06) | 0.26 (0.11) | 36.9 (11.6) |
| 75–79y | 641 | 449 (229) | 598 (293) | 0.16 (0.07) | 0.28 (0.12) | 39.1 (12.8) |
| ≥80y | 620 | 473 (241) | 626 (301) | 0.17 (0.08) | 0.30 (0.13) | 40.4 (12.9) |
| Male | | | | | | |
| 60–64y | 1644 | 412 (170) | 566 (217) | 0.15 (0.06) | 0.26 (0.09) | 37.8 (10.4) |
| 65–69y | 1485 | 428 (190) | 582 (237) | 0.16 (0.06) | 0.27 (0.10) | 38.5 (11.0) |
| 70–74y | 1156 | 439 (187) | 595 (239) | 0.16 (0.06) | 0.28 (0.10) | 39.3 (10.9) |
| 75–79y | 771 | 467 (201) | 632 (254) | 0.17 (0.07) | 0.29 (0.10) | 40.9 (11.2) |
| ≥80y | 745 | 523 (242) | 695 (293) | 0.19 (0.08) | 0.32 (0.12) | 43.5 (12.3) |
| Prior cataract surgery[a] | | | | | | |
| No | | | | | | |
| 60–64y | 3175 | 374 (156) | 511 (208) | 0.14 (0.05) | 0.24 (0.09) | 35.3 (10.4) |
| 65–69y | 2615 | 381 (168) | 514 (212) | 0.14 (0.06) | 0.24 (0.09) | 35.6 (10.6) |
| 70–74y | 1896 | 389 (161) | 526 (210) | 0.15 (0.05) | 0.25 (0.09) | 36.2 (10.4) |
| 75–79y | 1020 | 409 (178) | 546 (226) | 0.15 (0.06) | 0.26 (0.09) | 37.4 (10.7) |
| ≥80y | 855 | 430 (193) | 572 (241) | 0.16 (0.06) | 0.28 (0.10) | 38.6 (11.4) |
| Yes | | | | | | |
| 60–64y | 257 | 519 (221) | 720 (280) | 0.18 (0.07) | 0.32 (0.12) | 43.5 (12.2) |
| 65–69y | 350 | 566 (247) | 769 (296) | 0.20 (0.08) | 0.35 (0.13) | 45.8 (12.1) |
| 70–74y | 458 | 559 (231) | 762 (285) | 0.20 (0.07) | 0.34 (0.12) | 45.6 (11.9) |
| 75–79y | 392 | 589 (245) | 799 (298) | 0.20 (0.08) | 0.35 (0.13) | 47.0 (12.1) |
| ≥80y | 510 | 618 (271) | 817 (322) | 0.22 (0.08) | 0.37 (0.13) | 48.0 (12.6) |

AOD = angle opening distance; SSA = scleral spur angle; TISA = trabecular-iris space area

[a]Self-reported history of cataract surgery

**Table 3.**

**Diagnostic accuracy of anterior segment optical coherence tomography parameters, right eyes.**

The reference standard (i.e., narrow angles), defined as the absence of a visible trabecular meshwork for ≥ 180° on nonindentation gonioscopy, was present in 135 eyes and absent in 698 eyes. Two sets of cutpoints were calculated: the cutpoint that optimizes sensitivity and specificity (i.e. Youden index), and the cutpoint that provided 90% specificity.

| Statistic | AOD500, μm | AOD750, μm | TISA500, $mm^2$ | TISA750, $mm^2$ | SSA, ° |
|---|---|---|---|---|---|
| Optimal | | | | | |
| Cutpoint | 276 (240–290) | 367 (340–400) | 0.11 (0.09–0.12) | 0.18 (0.16–0.21) | 29 (26–30) |
| AUC | 0.87 (0.85–0.9) | 0.89 (0.87–0.92) | 0.85 (0.83–0.88) | 0.88 (0.85–0.90) | 0.87 (0.85–0.89) |
| Sensitivity | 85% (71–94%) | 87% (75–96%) | 79% (60–93%) | 83% (68–95%) | 86% (71–94%) |
| Specificity | 75% (68–83%) | 77% (71–83%) | 74% (64–88%) | 77% (66–88%) | 75% (69–83%) |
| 90% specificity | | | | | |
| Cutpoint | 195 (190–210) | 283 (270–290) | 0.07 (0.07–0.08) | 0.14 (0.13–0.15) | 22 (21–23) |
| AUC | 0.87 (0.84–0.9) | 0.89 (0.87–0.92) | 0.86 (0.83–0.88) | 0.88 (0.85–0.90) | 0.87 (0.84–0.9) |
| Sensitivity | 56% (46–65%) | 65% (54–74%) | 50% (36–69%) | 60% (47–72%) | 56% (46–66%) |
| Specificity | 91% (86–94%) | 91% (88–94%) | 91% (87–94%) | 91% (86–95%) | 91% (86–94%) |

AOD = angle opening distance; AUC = area under the receiver operating characteristics curve; SSA = scleral spur angle; TISA = trabecular-iris space area

**Table 4.**

**Optimal thresholds for predicting narrow angles from studies of anterior segment optical coherence tomography.**

All studies besides the present study enrolled participants from clinic-based settings. Parameters were estimated with the device's built-in software unless otherwise noted.

| | | | Narrow angle[a] | | Optimal threshold | | | |
|---|---|---|---|---|---|---|---|---|
| **Study city, year** | **Device** | **Type** | **−** | **+** | **AOD500 (μm)** | **AOD750 (μm)** | **TISA500 ($mm^2$)** | **TISA750 ($mm^2$)** |
| Cleveland, 2005[11] | Custom | TD | 23 | 8 | 191 | --- | 0.11 | 0.17 |
| Berlin, 2005[12] | 4Optics | TD | 77 | 61 | 290 | --- | --- | --- |
| San Francisco, 2009[13] | Visante[b] | TD | --- [c] | --- [c] | 244 | 342 | --- | --- |
| Singapore, 2010[14] | Visante[d] | TD | 1150 | 315 | 177 | 225 | 0.076 | 0.177 |
| Chandigarh, 2011[15] | RTVue | SD | 237 | 28 | 320 | --- | 0.21 | --- |
| Singapore, 2011[16] | Visante[d] | TD | 1652 | 395 | --- | 240 | --- | --- |
| Houston, 2016[17] | CASIA[e] | SS | 111[f] | 78[f] | 280 | 370 | 0.079 | 0.162 |
| Guangzhou, 2020[18] | CASIA | SS | 60[f] | 117[f] | 221 | 240 | 0.077 | 0.153 |
| Present study | Cirrus | SD | 698 | 135 | 268 | 353 | 0.11 | 0.18 |

AOD = angle opening distance; SD = spectral domain OCT; SS = swept source OCT TD = time domain OCT; TISA = trabecular-iris space area

[a] Narrow angles as assessed by gonioscopy

[b] Analyzed with UBM Pro2000 software (Paradigm Medical Industries, Salt Lake City, USA)

[c] Definition of narrow angles not specified; 303 total eyes, of which 6 had chronic angle closure, 34 had mixed mechanism glaucoma, and 88 had narrow anatomic angles.

[d] Analyzed with Zhonshan angle assessment program (ZAAP, Guangzhou, China)

[e] Analyzed with Anterior Chamber Analysis and Inteprretation software (ACAI, Houston, USA)

[f] Number of eyes from the training datasets used to determine optimal cutpoints