Agreement of angle closure assessments between gonioscopy, anterior segment optical coherence tomography and spectral domain optical coherence tomography

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Abstract

• **AIM: To determine angle closure agreements between gonioscopy and anterior segment optical coherence tomography (AS –OCT), as well as gonioscopy and spectral domain OCT (SD–OCT). A secondary objective was to quantify inter –observer agreements of AS –OCT and SD–OCT assessments.**

• **METHODS: Seventeen consecutive subjects (33 eyes) were recruited from the study hospital's Glaucoma clinic. Gonioscopy was performed by a glaucomatologist masked to OCT results. OCT images were read independently by 2 other glaucomatologists masked to gonioscopy findings as well as each other's analyses of OCT images.**

• **RESULTS: Totally 84.8% and 45.5% of scleral spurs were visualized in AS –OCT and SD –OCT images respectively (P <0.01). The agreement for angle closure between AS –OCT and gonioscopy was fair at k =0.31 (95% confidence interval, CI: 0.03–0.59) and k=0.35 (95% CI: 0.07–0.63) for reader 1 and 2 respectively. The agreement for angle closure between SD–OCT and gonioscopy was fair at k=0.21 (95% CI: 0.07 –0.49) and slight at k=0.17 (95% CI: 0.08–0.42) for reader 1 and 2 respectively. The inter –reader agreement for angle closure in AS –OCT images was moderate at 0.51 (95% CI: 0.13 –0.88). The inter –reader agreement for angle closure in SD –OCT images was slight at 0.18 (95% CI: 0.08–0.45).**

• **CONCLUSION: Significant proportion of scleral spurs were not visualised with SD –OCT imaging resulting in weaker inter –reader agreements. Identifying other angle landmarks in SD–OCT images will allow more consistent angle closure assessments. Gonioscopy and OCT imaging do not always agree in angle closure assessments but have their own advantages, and should be used together and not exclusively.**

• **KEYWORDS:** anterior segment imaging; spectral domain imaging; angle closure assessment

INTRODUCTION

Primary angle-closure glaucoma results from the closure of the anterior chamber angle in the eye, leading to a rise in intraocular pressure and damage to the optic nerve[1]. Accurate angle assessment is therefore important to ensure appropriate diagnosis and treatment. The current reference standard for angle assessment is gonioscopy. In the advent of newer imaging technologies, other techniques of angle assessment have been developed. Ultrasound biomicroscopy (UBM) has played an important role in angle imaging since the early 1990s [2]. However, it is a time-consuming and technician-dependent modality. UBM also requires contact with the globe, therefore reducing patient acceptability. In contrast anterior segment optical coherence tomography (AS-OCT, Visante, Carl Zeiss Meditec, Dublin, California, USA) is a non-contact, non-invasive angle imaging modality. It uses a 1310-nm diode laser to obtain real time images of the anterior chamber [3-5]. The scleral spur is a frequent landmark used in the assessment of angle closure. However, the low lateral resolution of AS-OCT images, image artifacts from eyelids and ocular structures, technical difficulties and

anatomical variations in eyes result in 20%-30% of scleral spurs not being visualized, prohibiting accurate and consistent angle closure assessment [6]. With the difficulty in visualizing angle closure qualitatively, some researchers have also started to use quantitative measurements of ocular biometric parameters like anterior chamber depth, anterior chamber width, anterior chamber volume, iris thickness, iris curvature, lens vault, lens thickness and lens position to predict angle closure [7-12]. However, although these ocular parameters have shown to have an association with angle closure, an imaging technology to visualize actual irido-trabecular contact would still be the ideal modality to confirm angle closure.

Spectral-domain OCT (SD-OCT) technology offers another means to acquire high definition optical coherence tomography images of angle structures. Compared to time-domain imaging technology, SD-OCT has a faster scan speed of up to 100 times (24 000-55 000 axial scans per second *vs* 400 axial scans per second) and higher axial resolution of up to 5 times (3.5-6 μm *vs* 10 μm)[13,14]. This results in less movement artifacts and higher quality images, which would allow for more accurate imaging of the anterior chamber angles. A limitation of SD-OCT is that it cannot easily obtain wide-field views of the anterior segment.

Currently most of the commercially available SD-OCT suites are used for imaging of the optic disc, retina and macula. Only a few SD-OCT machines have additional lens systems for anterior segment imaging. In some studies that reported SD-OCT images for angle assessments, the scleral spurs are not always clearly visualized[15,16]. There are also no reports to highlight inter-assessor agreements on angle closure assessments by OCT images.

This study aims to compare an anterior segment imaging feature of a commercially available SD-OCT instrument (Spectralis OCT, Heidelberg Engineering GmbH, Heidelberg, Germany) to AS-OCT. The study will specifically look at the frequency of scleral spurs being visualized in AS-OCT *vs* SD-OCT images, to compare SD-OCT *vs* AS-OCT agreements with gonioscopy on angle closure assessments and inter-reader agreements of AS-OCT and SD-OCT angle closure assessments.

SUBJECTS AND METHODS

Subjects The hospital-based study was approved by the National Healthcare Group (NHG) Domain Specific Review Board, overseen by NHG Research Ethics Committee. Consecutive consenting subjects were recruited from the Glaucoma clinic in Tan Tock Seng Hospital, Singapore. All study participants gave informed consent, which adhered to the tenets of the Declaration of Helsinki. Inclusion criteria for the study were subjects with normal tension glaucoma, primary open angle glaucoma, narrow angles, primary angle

closure, or primary angle closure glaucoma. Subjects had to be between 21 to 92y of age. Exclusion criteria were pre-existing corneal or retinal pathology, significant media opacities, history of eye trauma, and inability to provide informed consent. For each study subject, all assessments were performed within the same week. Assessments included slit lamp biomicroscopy, gonioscopy, AS-OCT and SD-OCT imaging.

Methods Gonioscopy was performed by a single glaucomatologist masked to AS-OCT and SD-OCT assessment results. Static and dynamic gonioscopy was performed in the dark with a Goldmann 2-mirror lens for static assessment and Sussman 4-mirror lens at high magnification (×16) for dynamic assessment. Examined eyes were in primary position of gaze. A narrow slit beam, 1 mm tall, was cast during gonioscopy, avoiding direct illumination over the pupil. The angle in each quadrant was graded with the Scheie grading system [17] (Grade I: visible ciliary body; Grade II: visible scleral spur; Grade III: visible anterior trabecular meshwork; Grade IV: no visible structure seen). Angle quadrants were considered closed if they were Scheie grade III or IV).

SD-OCT imaging of the nasal and temporal angle quadrants was performed with an anterior segment module lens, mounted over commercially available SD-OCT (Spectralis® OCT, Heidelberg Engineering GmbH, Heidelberg, Germany) imaging aperture. Imaging was performed in dark room conditions (0 lx) with the angle imaging software application. The patients were imaged gazing straight ahead *via* aid of external fixation lights. Imaging of a single meridional section of the anterior chamber angle at 3 and 9 o'clock was performed. The eye tracking function and image averaging function of the Spectralis® OCT (9 scans averaged) in the SD-OCT suite were utilised.

AS-OCT imaging of nasal and temporal angle quadrants were performed in the same external room lighting conditions as SD-OCT imaging with commercially available AS-OCT device (Visante; Carl Zeiss Meditec, Dublin, California, USA).

Image OCT images were graded independently by 2 other glaucomatologists, masked to gonioscopy findings, as well as each other's analyses of OCT images. The images were presented to the readers in a black image format over a white background (Figures 1, 2). The readers reviewed digital copies of the images, and were allowed to adjust the magnification and contrast as they wished during the grading process. The image readers were asked to observe only the nasal and temporal angle quadrants and to comment if they could distinctively identify scleral spurs in those quadrants. In addition, the readers were also asked to grade if the nasal and temporal angle quadrants were open or closed. OCT images

Figure 1 AS−OCT open.

Figure 2 SD−OCT presumed closed.

were graded closed if the image readers assessed any degree of irido-trabecular contact, regardless of whether they could visualise the scleral spur.

Statistical Analysis Data was managed *via* Microsoft Excel software, and statistical analyses performed with IBM SPSS Statistics (version 19, IBM Corp, New York, USA). McNemar's test was used for comparison of visualisation of scleral spurs in AS-OCT *vs* SD-OCT images. Cohen's Kappa was calculated to assess angle closure agreements between gonioscopy and OCT images, as well as agreements between the 2 observers grading the OCT images.

RESULTS

A total of 18 subjects consented for the study, however one subject requested to pull out later in the study due to personal reasons.

Thirty-three eyes (66 angle quadrants) from 17 subjects were analysed (A patient had one eye excluded due to chronic retinal detachment). The subjects' age ranged from 53 to 84y, with a mean±standard deviation age of 67.5±10.39y. Of the 17 subjects, 7 (41.2%) were females and 10 (58.8%) males. The race distribution was reflective of the non-homogenous multi-racial Singapore population, with 13 (76.4%) Chinese, 2 (11.8%) Malays and 2 (11.8%) Indians.

Visualisation of the Scleral Spur AS-OCT imaging allowed visualisation of the scleral spur by the image readers in 112 of the 132 (84.8%) angle quadrants reviewed in total by the 2 readers. In contrast, SD-OCT imaging allowed visualisation of the scleral spur only in 60 (45.5%) of the angle quadrant images (Table 1). The difference was statistically significant ($P<0.01$).

Agreements of the OCT Images with Gonioscopy The angle closure assessments from SD-OCT and AS-OCT images were compared to gonioscopy assessments in the same angle quadrants. The agreement for angle closure between AS-OCT and gonioscopy was fair at k =0.31 (95% CI: 0.03-0.59) and k =0.35 (95% CI: 0.07-0.63) for reader 1 and 2 respectively. The agreement for angle closure between SD-OCT and gonioscopy was fair at k =0.21(95% CI: 0.07-0.49)

Table 1 Number of scleral spurs visualised

Measurements	Scleral Spurs Visualised in the 132 Angles Quadrants Studied, No. (%)
AS-OCT	112 (84.8)
SD-OCT	60 (45.5)

Table 2 Agreements between OCT imaging and gonioscopy

Parameters	k (95% CI)
Agreements between AS-OCT and gonioscopy	
Reader 1	0.31 (0.03-0.59)
Reader 2	0.35 (0.07-0.63)
Agreements between SD-OCT and gonioscopy	
Reader 1	0.21 (0.07-0.49)
Reader 2	0.17 (0.08-0.42)

Table 3 Inter-reader agreements

Parameters	k (95% CI)
AS-OCT Inter-reader agreements	0.51 (0.13-0.88)
SD-OCT Inter-reader agreements	0.18 (0.08-0.45)

and slight at k =0.17 (95% CI: 0.08-0.42) for readers 1 and 2 respectively (Table 2).

Inter−reader Agreement of OCT Images (SD−OCT *vs* AS−OCT) Two glaucomatologists independently read the same AS-OCT and SD-OCT images of the angle quadrants assessed. The inter-reader agreement for angle closure in AS-OCT images was moderate at 0.51 (95% CI: 0.13-0.88). The inter-reader agreement for angle closure in SD-OCT images was slight at 0.18 (95% CI: 0.08-0.45; Table 3).

DISCUSSION

Visualisation of the scleral spur on OCT images is important for angle closure assessments as it provides a reference for the relative position of the trabecular meshwork. In our study, 84.8% of scleral spurs were visualised in AS-OCT angle imaging which was comparible to results from other AS-OCT studies [5] (Figure 1). In contrast, only 45.5% of scleral spurs were visualized with SD-OCT imaging. This could be due to the difference in wavelength of the lasers in the different machines, affecting penetration and imaging of the scleral spur. The lower rate of scleral spur visualisation with

SD-OCT imaging compared to other studies could also be possibly due to racial differences in our Asian population with increased pigmentation of scleral and conjunctival tissue affecting laser penetration.

Although only 45.5% of scleral spurs were visualized in the SD-OCT images, the OCT image readers were still able to grade 94.7% of angle quadrants as open or closed. These were angles that were clearly open, with iris base going into the ciliary body, or angles that were clearly closed, with large areas of iris contact anterior to iris insertion (Figure 2). Other reports have proposed that as scleral spurs are not always visible in SD-OCT imaging, other landmarks such as the Schwalbe's line should be considered for consistent and objective assessment of angle closure[8,18].

Our study showed that the angle closure agreement between AS-OCT and gonioscopy was stronger than that of SD-OCT and gonioscopy. Wong *et al* [15] suggested that the angle-closure disagreement between SD-OCT and gonioscopy could be due to the SD-OCT images being distorted as they are not dewarped or corrected for the index of refraction transition at the air-tear interface and the different group indexes in air, cornea and aqueous. Being accustomed to using the scleral spur as a landmark in AS-OCT images, the lower proportion of scleral spurs being visualised in the SD-OCT images could also have contributed to this finding.

Most of the disagreements between gonioscopy and OCT imaging for angle-closure assessments (87.12% of disagreements for AS-OCT, 71.16% of disagreements for SD-OCT) were noted in closed angles (on gonioscopy). Possible reasons for this could be that angles with steep "over-the-hill" iris configuration would be described as closed on gonioscopy but truly open on OCT imaging [19]. Mechanical distortion of the cornea during gonioscopy could possibly also make the angles appear artificially narrow[10,20].

The other rarer disagreements in which angles were open on gonioscopy and but closed on OCT imaging could be due to the increased lighting condition or inadvertent indentation during gonioscopy which may result in the artificial opening of angles[12,21].

In this study, the inter-reader agreements for angle closure assessments were stronger for AS-OCT than SD-OCT. The likely reason for this is that the higher rates of scleral spurs seen allowed a more consistent and objective method to angle assessment for both readers. In angle assessments with SD-OCT images, the 2 readers would have to use less objective means to grade the angles which could have affected consistency and inter-reader agreements. However, with more experience using other landmarks such as the Schwalbe's line, inter-reader agreements for SD-OCT may increase in the future.

Our study had some limitations. It was a small study with 17 patients and 33 eyes investigated. There was only 1 gonioscopy assessor which could have resulted in a systematic bias. The fixation lighting intensity of AS-OCT and SD-OCT machines could not be standardised. The OCT image readers had more experience reading AS-OCT images over SD-OCT images for angle closure assessments and there was no standardised training for them in the assessment of the SD-OCT images.

In summary, we found that a significant proportion of scleral spurs were not visualised with SD-OCT imaging possibly resulting in weaker inter-reader agreements on angle closure assessments. Identifying other angle landmarks in SD-OCT images will allow more consistent angle closure assessments with this new technology. Gonioscopy and OCT imaging may not always agree in angle closure assessments. However, each assessment modality has its own advantages (gonioscopy can distinguish appositional versus synechial angle closure, OCT imaging is more objective, and rapidly performed with no patient discomfort) and should be used together and not exclusively.

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