Use of EyeCam for Imaging the Anterior Chamber Angle

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PURPOSE. To compare EyeCam (Clarity Medical Systems, Pleasanton, CA) imaging with gonioscopy for detecting angle closure.

METHODS. In this prospective, hospital-based study, subjects underwent gonioscopy by a single observer and EyeCam imaging by a different operator. EyeCam images were graded by two masked observers. The anterior chamber angle in a quadrant was classified as closed if the trabecular meshwork could not be seen. The eye was classified as having angle closure if two or more quadrants were closed.

RESULTS. One hundred fifty-two subjects were studied. The mean age was 57.4 years (SD 12.9) and there were 82 (54%) men. Of the 152 eyes, 21 (13.8%) had angle closure. The EyeCam provided clear images of the angles in 98.8% of subjects. The agreement between the EyeCam and gonioscopy for detecting angle closure in the superior, inferior, nasal, and temporal quadrants based on agreement coefficient (AC1) statistics was 0.73, 0.75, 0.76, and 0.72, respectively. EyeCam detected more closed angles than did gonioscopy in all quadrants (P < 0.05). With gonioscopy, 21/152 (13.8%) eyes were diagnosed as angle closure compared to 41 (27.0%) of 152 with EyeCam (P < 0.001, McNemar Test), giving an overall sensitivity of 76.2% (95% confidence interval [CI], 54.9%–90.7%), specificity of 80.9% (95%CI, 73.5%–87.3%), and an area under the receiver operating characteristic curve (AUC) of 0.79.

CONCLUSIONS. The EyeCam showed good agreement with gonioscopy for detecting angle closure. However, it detected more closed angles than did gonioscopy in all quadrants. (Invest Ophthalmol Vis Sci. 2010;51:2993–2997) DOI:10.1167/ iovs.09-4418

G onioscopy is the current reference standard for assessing the anterior chamber angle (ACA). The advantages of gonioscopy include the ability to visualize a whole quadrant of the ACA at one time, the use of the corneal wedge to help identify landmarks in the angle such as Schwalbe’s line, and the ability to dynamically indent the angle and distinguish peripheral anterior synechiae (PAS) from appositional closure. Various grading schemes have been developed to categorize eyes on the basis of gonioscopic assessment of the ACA,¹–³ but such schemes are based on subjective and at best semiquantitative assessments. However, factors such as the type of lens used, the technique used, and the skill of the observer affect the variability of gonioscopy findings.⁴ Documentation of gonioscopic findings is often poor, with most clinicians recording them in charts without images or photographic records.

The EyeCam (Clarity Medical Systems, Pleasanton, CA) is an imaging modality that was originally designed to obtain wide-field photographs of the fundus. It has recently been used in glaucoma management to image the optic disc⁵ and the anterior chamber angle.⁶ With the use of 120° and 130° wide-field lenses, high-resolution anterior segment images of the iris and ACA can be obtained (Fig. 1). The hardware consists of a hand-held digital video camera connected fiberoptically to a light-emitting control unit and computer assembly. The operator controls focus, illumination, and the acquisition of images with a foot switch. Images are automatically saved to a computer hard drive. Alternatively, a short video stream can be captured, with still frames selected from the video and saved at the end of the imaging session.

The purpose of this study was to evaluate the use of the EyeCam for angle imaging and to assess its diagnostic performance in detecting angle closure using gonioscopy as the reference standard.

METHODS

Consecutive subjects were recruited from a glaucoma clinic at a Singapore hospital from July to October 2008. Written informed consent was obtained from all participants. The study had the approval of the hospital’s Institutional Review Board and adhered to the tenets of the Declaration of Helsinki.

After an interview about medical and ophthalmic history, each subject underwent the following examinations on the same day: visual acuity, gonioscopy, and imaging with the EyeCam. Subjects were excluded if they were taking any topical medications that had an effect on the pupil size, had a history of cataract surgery or any corneal opacity or abnormalities that precluded EyeCam imaging. A history laser iridotomy was not an exclusion criterion.

Gonioscopy

Gonioscopy was performed in the dark in all cases by a single examiner with glaucoma fellowship training (SAP), who was masked to EyeCam findings. A 1-mm light beam was reduced to a narrow slit and the vertical beam was offset horizontally for assessing superior and inferior angles and offset vertically for nasal and temporal angles. Static gonioscopy was performed with a Goldmann two-mirror lens at high magnification (×16), with the eye in the primary position of gaze. Care was taken to avoid light falling on the pupil and to avoid accidental 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 distortion of the angle. The angle in each quadrant was graded using the Scheie grading system according to the anatomic structures observed during gonioscopy.⁷ The ACA was considered...
closed in that quadrant if the posterior pigmented trabecular meshwork (TM) could not be seen in the primary position without indentation. The eye was classified as having angle closure if there were two or more quadrants of closure. Any doubt as to the state of the angle or any suspicion of PAS was confirmed on indentation gonioscopy with a Sussman lens. PAS were defined as abnormal adhesions of the iris to the angle that were present to the level of the anterior trabecular meshwork or higher, and were deemed to be present if apposition between the peripheral iris and angle structures could not be broken despite indentation gonioscopy.

**EyeCam Imaging**

After gonioscopy, EyeCam imaging was performed on subjects who lay supine on a couch in a darkened room. Images were captured by a single trained technician (TAT) in all four quadrants of the left eye of all subjects, unless any exclusion criteria were present, in which case the right eye was imaged. The technician was trained on the technical details of EyeCam imaging and had basic knowledge of angle anatomy and structures. After instillation of topical anesthetic eye drops (proparacaine hydrochloride 0.5% ophthalmic solution; Alcon Laboratories, Inc., Fort Worth, TX), coupling gel was applied to the anesthetized eye, before imaging proceeded with a 130° lens held next to the limbus. The illumination light was pointed at the angle rather than the pupil, to minimize any pupillary dilatation. If the angle was not visible due to pronounced convexity of the iris, the probe was moved anteriorly within 10° of the limbus to gain a view over the convexity of the iris. The illumination was adjusted using the foot pedal to avoid overexposure. Clear still images were captured to the hard disc of the attached computer for subsequent grading. Imaging of all four quadrants of the eye was performed in less than 5 minutes.

**Grading of the Images**

EyeCam images were graded in each quadrant by two fellowship-trained glaucoma specialists (TA and MB) working together, who were masked to the gonioscopic data. Images were first graded for their quality as follows: grade 1 if the angle details were clear and well focused in all quadrants; grade 2 if angle images were blurred in any quadrant but some details discerned; grade 3 if the angle structures were blurred in at least one quadrant such that no details can be discerned; and grade 4 if the structures were blurred in all four quadrants and no angle details were discerned. Images were excluded if they were assessed to be grade 3 or 4.

The angle-grading scheme for each quadrant was similar to that used for gonioscopy and was based on anatomic structures observed in the ACA (Fig. 2A). The final grading of a quadrant was determined by the most prevalent grade seen in that quadrant. For EyeCam images, angle closure in any quadrant was defined as the inability to visualize the TM in that quadrant (Fig. 2B), and the eye was considered to have angle closure if the TM was not visible in at least two quadrants.

To examine for intraobserver reproducibility of image grading, the images from 40 (26.31%) of 152 randomly selected eyes were graded again at a different session by one of the examiners (MB), masked to previous grading, for angle structures in each quadrant and for angle pigmentations.
Table 1. Analysis of the Eyes with Closed Quadrants Detected by EyeCam and Gonioscopy (n = 152)

<table>
<thead>
<tr>
<th>Eyes with the following number of closed quadrants</th>
<th>Gonioscopy n (%), 95% CI</th>
<th>EyeCam n (%), 95% CI</th>
<th>P*</th>
<th>AC1†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 (9.9–15.4)</td>
<td>7 (4.6–8.99)</td>
<td>0.1</td>
<td>0.86</td>
</tr>
<tr>
<td>2</td>
<td>8 (5.3–10.2)</td>
<td>11 (7.2–9.2)</td>
<td>0.65</td>
<td>0.73</td>
</tr>
<tr>
<td>3</td>
<td>7 (4.6–9.4)</td>
<td>10 (6.8–11.8)</td>
<td>0.61</td>
<td>0.89</td>
</tr>
<tr>
<td>4</td>
<td>6 (4.6–8.5)</td>
<td>20 (13.8–19.8)</td>
<td>&lt;0.01</td>
<td>0.86</td>
</tr>
<tr>
<td>Eyes with closed quadrants by location</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td>25 (15.1–21.5)</td>
<td>34 (22.5–29.7)</td>
<td>0.04</td>
<td>0.73</td>
</tr>
<tr>
<td>Inferior</td>
<td>25 (15.0–21.5)</td>
<td>35 (23.9–30.2)</td>
<td>0.05</td>
<td>0.75</td>
</tr>
<tr>
<td>Nasal</td>
<td>21 (13.8–8.9–20)</td>
<td>36 (23.8–31.1)</td>
<td>0.004</td>
<td>0.76</td>
</tr>
<tr>
<td>Temporal</td>
<td>10 (6.6–11.4)</td>
<td>34 (22.4–29.5)</td>
<td>&lt;0.001</td>
<td>0.72</td>
</tr>
<tr>
<td>Eyes with angle closure using different definitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ Two quadrants</td>
<td>21 (13.8–8.9–20)</td>
<td>41 (27.0–34.5)</td>
<td>&lt;0.001</td>
<td>0.71</td>
</tr>
<tr>
<td>≥ Three quadrants</td>
<td>13 (8.6–14.2)</td>
<td>30 (19.7–26.8)</td>
<td>&lt;0.001</td>
<td>0.78</td>
</tr>
</tbody>
</table>

* McNemar test
† Interinstrument agreement based on AC1 statistics.

Results

Of the 169 subjects recruited, 15 were excluded for incomplete or missing data. Two subjects (1.2%) were excluded due to poor quality (grade 3 or 4) of EyeCam images. A total of 152 eyes of 152 subjects were finally analyzed, comprising 25 (3.8%) of 608 images that were grade 2 and 585 (96.2%) of 603 images that were grade 1. The mean age was 57.4 years (SD 12.9 years) and there were 82 (54%) men. The majority of subjects were Chinese (80.3%), and the remainder were Malay (4.6%), Indian (7.9%), and other races (7.2%). Of the 152 eyes, 21 eyes (13.8%) had angle closure (6 had suspected primary angle closure [PACS], 4 primary angle closure [PAC], and 11 were primary angle closure glaucoma [PACG]). Among these, 15 eyes had previous laser peripheral iridotomy performed.

The agreement between EyeCam and gonioscopy in detecting a closed angle in the superior, inferior, nasal, and temporal quadrants based on AC1 statistics was 0.73, 0.75, 0.76, and 0.72, respectively (Table 1). EyeCam detected more closed angles than gonioscopy in all quadrants (P < 0.05).

With gonioscopy, 21 (13.8%) of 152 eyes were diagnosed as angle closure compared with 41 (27.0%) with EyeCam (P < 0.001, McNemar Test), giving an overall sensitivity of 76.2% (95% confidence interval [CI], 54.9–90.7%), specificity of 80.9% (95% CI, 73.5–87.3%), and an area under the receiver operating characteristic curve (AUC) of 0.79. The agreement between the two modalities, according to AC1 stats, varied depending on the definition of angle closure used (summarized in Table 1).

Reproducibility Analysis

The intraobserver reproducibility (image grading) for detecting angle closure in two quadrants or more using EyeCam images was 0.57 (AC1) and 0.43 (κ; 95% CI, 0.13–0.74); and that of interobserver agreement was 0.64 (AC1) and 0.49 (κ; 95% CI, 0.20–0.79; Table 2) respectively. In terms of reproducibility of image acquisition, there was good intraobserver reproducibility for angle closure detection (0.84 [AC1] and 0.73 [κ; 95% CI, 0.38–1.08]).

Table 2. The Inter- and Intraobserver Agreement in Detecting Closed Quadrants and Detecting Overall Angle Closure Status Using EyeCam and Gonioscopy

<table>
<thead>
<tr>
<th>Quadrants</th>
<th>Interobserver Agreement</th>
<th>Intraobserver Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>κ (95% CI)</td>
<td>AC1</td>
</tr>
<tr>
<td>Superior</td>
<td>0.63 (0.38–0.88)</td>
<td>0.67</td>
</tr>
<tr>
<td>Inferior</td>
<td>0.59 (0.31–0.87)</td>
<td>0.70</td>
</tr>
<tr>
<td>Nasal</td>
<td>0.39 (0.06–0.72)</td>
<td>0.58</td>
</tr>
<tr>
<td>Temporal</td>
<td>0.40 (0.06–0.75)</td>
<td>0.65</td>
</tr>
<tr>
<td>Angle closure</td>
<td>0.49 (0.20–0.79)</td>
<td>0.64</td>
</tr>
</tbody>
</table>

* Defined as closure in two quadrants or more.
DISCUSSION

In this study, we found good agreement between EyeCam angle imaging and clinical gonioscopy for detecting quadrants with closed angles. However, for detecting eyes with angle closure, there was a higher rate of angle closure diagnosed by EyeCam compared with gonioscopy, with a sensitivity and specificity of 76.2% and 80.9% respectively (AUC 0.79), using the two quadrant definition of angle closure. The EyeCam was able to obtain clear images of the angles in 98.8% of studied individuals, with imaging performed by a technician. This difference in findings between the EyeCam and gonioscopy could be due to numerous factors including patient positioning (the patient is supine for the EyeCam and seated for gonioscopy), different degrees of illumination (although light is needed for both assessments), and the optics used in the EyeCam to image the angle. Of note, the light used for EyeCam is quite bright and although no flash was used, the light would have an effect on pupillary constriction. The probe is placed 180° across from the angle being imaged and requires a direct line of sight to see angle structures. However, a convex iris profile can block the camera from angle structures. EyeCam imaging revealed a very uniform distribution of closed quadrants across all four quadrant locations of the eye, in contrast to gonioscopy which showed a trend toward more closure in the inferior and superior quadrants, supporting previous gonioscopic and anterior segment optical coherence tomography (AS-OCT) data.9,10

The EyeCam offers advantages over other angle imaging methods. It provides a direct, color view of the angle with excellent optical quality, similar to that provided by gonioscopy. The number of poor-quality images is low (~1% in our study), and a technician can perform EyeCam easily after a short period of training. In contrast, in a previously published large community-based study of AS-OCT for the detection of angle closure, 16% (a significant proportion) of eyes could not be assessed for angle closure, mainly due to poor quality images or poor visibility of the scleral spur.11 Goniphotography using a slit lamp–mounted camera is another method of angle imaging that is similar to EyeCam. However, slit lamp goniphotography is technically challenging, and it is not easy to obtain good-quality images. We are currently performing a study comparing EyeCam with slit lamp goniphotography.

In some EyeCam images, we identified structures that resemble PAS (Fig. 2C). However as indentation could not be performed, the EyeCam could not be used to conclusively differentiate PAS from iris processes. This is a limitation of the device. Indentation gonioscopy is the reference standard approach to distinguish between appositional and synchial angle closure.12 Furthermore, being unable to dynamically indent the eye made it difficult at times to distinguish TM pigment from pigment on Schwalbe’s line. The interpretation of EyeCam images in eyes with lightly pigmented TM may be difficult, whereas gonioscopy has the advantage of using the corneal wedge as a landmark to identify the anterior edge of the TM. These reasons may have contributed to the moderate intra- and interobserver agreement found in the interpretation of EyeCam images. This level of agreement is lower than that seen when interpreting AS-OCT images.13

Current documentation of the angle in patient records is often subject to a variety of different classification systems and can be difficult to interpret. The EyeCam may have potential for documenting a 360° view of the angle, which could then be interpreted by any observer. This would be useful for documentation in clinical charts. The EyeCam also delivers images that show more than simply the angle width, it can show pigment and new vessels (although not evaluated in this study), that cannot be imaged by the cross-sectional imaging modalities. However, quantitative analysis is not yet possible with the EyeCam. As trained technicians can efficiently capture the images, the EyeCam could be used alongside the ophthalmologist’s clinical examination for referral consultations or for education.

Our study has some limitations. The use of a single observer for gonioscopy could have led to a systematic bias. EyeCam was performed on supine patients, whereas gonioscopy was performed on patients sitting at the slit lamp. As mentioned, the lighting conditions for EyeCam and gonioscopy were different. The images seen with the EyeCam gave a good 90° view or more of the angle, but there is some degradation of the images at the periphery that are related to optical aberrations and depth of field. The reproducibility of EyeCam image grading was only moderate. This is a concern because clinical decisions based on the EyeCam images may vary depending on the grader. The proportion of subjects with angle closure was quite low (13.8%) in this sample and may partly explain the wide confidence intervals seen in reproducibility analyses for angle closure detection. Should the EyeCam be used more widely, it may be necessary to devise more elaborate training and create standard photos in an attempt to improve the reproducibility. Overall, we believe that the EyeCam’s limitations include the high cost, variable angle of view, effect of illumination and gravity, learning curve for the operator, moderate to poor reproducibility, inability to distinguish appositional from synchial closure as PAS cannot be identified, and difficulty in identifying angle structures in eyes with light pigmentation. The strengths of the study stem from the fact that standard definitions and grading system were used for angle closure and a large number of eyes have been imaged. Also, the assessment of EyeCam images was performed by graders masked to the gonioscopic data.

In summary, this initial study showed a good degree of agreement between EyeCam angle imaging and clinical gonioscopy, with moderate sensitivity and specificity for detecting angle closure. The EyeCam has potential for use in anterior segment imaging, particularly in the clinical setting for documentation of angle findings. However, due to several inherent limitations, it cannot be recommended as a screening tool for detection of angle closure and cannot be used to distinguish PACs from PAC or PACG, as it cannot identify PAS.

References


