Defining “occludable” angles in population surveys: drainage angle width, peripheral anterior synechiae, and glaucomatous optic neuropathy in east Asian people


Background/aim: A current consensus in epidemiological studies of primary angle closure (PAC) is to diagnose the condition only if the posterior (usually pigmented) trabecular meshwork is seen for less than 90° of the angle circumference, termed an “occludable angle.” The authors sought to assess the validity of this epidemiological classification by exploring the relation between drainage angle width, peripheral anterior synechiae (PAS) and glaucomatous optic neuropathy (GON).

Methods: 918 Mongolians and 995 Chinese Singaporeans, both groups aged 40 years and older were examined in two population based surveys. Gonioscopic angle width was graded in five categories (0 = closed to 4 = wide open) according the scheme described by Shaffer. Cases with secondary PAS were excluded.

Results: The rate of PAS was between 0.3% and 1.7% in people with wide angles (grades 3 and 4). In those with grade 2 angles, PAS were seen in between 8% of eyes. In eyes with grade 1 angles, the rate rose to 17% in Chinese Singaporeans, and 31% in Mongolians. The odds of PAS were higher in people with narrower angles. However, there was a greater absolute number of people with PAS whose drainage angles were classified as “not occludable” than those classified “occludable.”

Conclusions: The traditional view that primary angle closure becomes a significant possibility in drainage angles of ≤ grade 2 (approximately 20°) is invalid in east Asians. The definition of an “occludable” angle examined here excludes many people with PAS. This probably serves to under-emphasise the role of PAC in population surveys of glaucoma prevalence in Asian people.

Primary angle closure glaucoma (PACG) is a leading cause of blindness in east Asian people. In epidemiological research, cases of primary glaucoma are usually divided into PACG and primary open angle glaucoma (POAG) on the basis of a subjective judgment on the likelihood of iridotrabecular apposition. A consensus definition of the characteristics an “occludable” drainage angle has come into common usage in epidemiological research. If the posterior (usually pigmented) trabecular meshwork is seen for less than 90° of angle circumference, this is termed an occludable angle. However, this remains an arbitrary division that has not been validated.

Peripheral anterior synechiae (PAS) are acquired adhesions between the corneoscleral coat and the peripheral iris. They are seen as the hallmark of primary angle closure (PAC). The lesions may vary in height and width. In the earliest stages they are narrow and may extend only as far as the posterior part of the trabecular meshwork in a sawtooth shape. As the process of angle closure progresses, the adhesions extend anteriorly across the trabecular meshwork and spread circumferentially. Typically, PAS, in an intermediate phase of the closure process are multifocal, having a broad base and blunt apex. The extent of PAS correlates with the likelihood of both glaucomatous optic neuropathy, and for laser peripheral iridotomy being deemed insufficient to control the disease.

In this analysis, we sought to investigate the association between width of the drainage angle and the presence of PAS. Furthermore, we were interested to assess the rate of both synechiae and glaucomatous optic neuropathy (GON) in people with and without an “occludable” drainage angle, in order to assess the validity of our assumptions regarding a causal relation between these two clinical entities.

METHODS
The subjects for this study were recruited during two population surveys of glaucoma prevalence in east Asian people. Ethical approval for these projects was obtained from the Mongolian Ministry of Health and the ethics review board of Singapore National Eye Centre. The work was carried out in accordance with The World Medical Association’s Declaration of Helsinki. The methodology of the examination in both Mongolia and Singapore has been described previously. A summary is given below.

In Hövsgol province, Mongolia, 1000 subjects aged 40 years and over were chosen from the local government population register, representing 4.8% of the province’s population in this age group. The subjects were drawn from urban (400 people) and rural areas (600 people), using a combination of clustered, random, and systematic sampling.

The electoral register of Tanjong Pagar district in Singapore was used to identify 2000 Chinese subjects from this population (13.3% of the total), using a disproportionate, stratified, clustered, random sampling procedure. Subjects were drawn randomly, approximately 500 from each of five age strata: 40–49, 50–59, 60–69, and 70–79 years, residing in 50 area clusters defined by street name. The proportion of men and women was determined by the sex ratio of that age group in the district.

Gonioscopy was carried out in all patients using a Goldmann style 2 mirror gonioscope. The examination of

Abbreviations: GHT, glaucoma hemifield test; GON, glaucomatous optic neuropathy; PAC, primary angle closure; PACG, primary angle closure glaucoma; PAS, peripheral anterior synechiae; POAG, primary open angle glaucoma; vCDR, vertical cup:disc ratio
all subjects was carried out at a low level of ambient illumination throughout. A 1 mm beam of light was reduced to a very narrow slit. Care was taken to avoid light falling on the pupil during gonioscopy. The assessment was carried out at high magnification (×16 in Mongolia, ×25 in Singapore). Slight tilting to gain a view over the convexity of the iris was permitted, but further manipulation of the lens or redirection of gaze was avoided because of the possibility of exerting pressure on the cornea and artificially widening the angle.

The width of the angle was estimated in four quadrants as the angle in degrees between a tangent to the surface of the trabecular meshwork and a tangent to the peripheral third of the iris. This was recorded on a five point categorical scale (0°, 10°, 20°, 30°, ≥40°) according to the scheme described by Shaffer.7 The mean angle width for an eye was calculated by adding the angle grade for each quadrant and dividing by 4. The drainage angle was then graded as occludable or not using a dichotomous modification of the Scheie scheme (based on angle structures seen).16 If the posterior (usually pigmented) trabecular meshwork could be seen for less than 90° of the angle circumference, the angle was classified as “occludable.” Dynamic (compression) gonioscopy was used to detect the presence of PAS, unless all angle structures could be clearly identified in a wide open angle. The examination was carried out using either the Goldmann lens or a four mirror gonioscope (Mongolia: Zeiss model, Clement Clark, Harlow, UK, and Singapore: “Sussmann” model, Ocular Instruments, Bellevue, WA, USA). PAS were graded present or absent in four quadrants. Slit lamp examination was used to identify subjects with ocular pathology or surgery that may have caused secondary PAS. These people were excluded from analysis. All gonioscopic examinations were carried out by the same investigator.

Glaucomatous optic neuropathy (GON) was diagnosed if both a statistical abnormality of the vertical cup:disc ratio (vCDR) and a reproducible visual field abnormality were present in the same eye. If a subject’s visual function was so severely affected to prevent reliable visual field testing, the diagnosis was made on the grounds of a severely abnormal vCDR.6 In Mongolia, the optic disc and posterior pole were examined using a +90D lens through the undilated pupil. If a satisfactory view was not obtained or if an inexplicable field defect was detected the pupil was dilated with 0.5% tropicamide (Alcon Laboratories, Hemel Hempsted, UK) after gonioscopy, provided the angle was not judged to be occludable. The central visual field was examined using a Henson CFA 3000 (Tinsley Medical Instruments, Croydon, UK). Reproducible field defects (at least two adjacent points, contiguous points (p ≤0.5%) on the pattern deviation plot not crossing the horizontal meridian were considered compatible with glaucoma.

Odds ratios and their confidence intervals, and the confidence intervals of rates, were calculated using the CIA software package (BMJ Publishing Group, London, UK). Logistic regression was used to examine the relation between glaucomatous optic neuropathy and both PAS and occludable angles, while correcting for the effect of age and sex. Logistic regression was carried out using SPSS software (SPSS Inc, Chicago, IL, USA).

**RESULTS**

In Mongolia, 942 subjects were examined, representing 94.2% of those selected within the sampling frame. In Singapore, 2000 names were selected. Of these, 283 were considered ineligible on the grounds that they had either died (46), were severely ill (two), or had moved away from the study area (235). From the remaining 1717 eligible subjects, 1090 people were examined at the research clinic (63.5%). A further 142 people were examined in their homes, although they underwent a less detailed examination. Data were therefore presented for the 1090 subjects examined in the research clinic.

In Mongolia, complete data on drainage angle width, the presence or absence of PAS in all quadrants, and grading of occludable/non-occludable angle in right eyes were available for 921 of 942 subjects. Two aphakic subjects and one person with evidence of previous severe keratouveitis had PAS in eyes with otherwise wide open angles. These three people were excluded leaving data on 918 subjects for this analysis. When examining the role of PAS in the development of GON, the optic disc status of two subjects could not be determined because of media opacities. These people were excluded leaving 13 with GON and 903 normal subjects.

In Singapore, PAS were identified in 42% (= 34/80) of people who had undergone cataract surgery. A further seven people had PAS associated with glaucoma surgery, three subjects had either iris neovascularisation or evidence of significant trauma, and data were incomplete for another five people. These 95 subjects (80+7+3+5) were excluded from analysis, leaving data on 955 subjects (91.2% of all those selected). Of these, 10 had GON and complete data on angle characteristics.

Table 1 gives the age and sex distribution of subjects included in this analysis. Table 2 summarises the rate of PAS according to Shaffer angle width in the right eyes of Mongolians and Singaporeans. The rate of PAS and the odds of PAS increased as angle width decreased.

Table 3 gives the rate of PAS in people with and without an angle graded “occludable.” Although there were fewer eyes with PAS and an occludable angle than those with angles “not occludable,” the odds of PAS in occludable angles was 21.5 (95% CI: 9.9 to 46.9) for Mongolian people and 6.6 (95% CI: 3.3 to 13.4) for Chinese Singaporeans.

Table 4 summarises the relation between PAS and GON. Among Mongolian people, 16.7% (95% CI: 7.3 to 33.6) with PAS had GON, compared with 0.9% (95% CI: 0.5 to 1.8) without in four quadrants. All subjects with PAS and GON had either undergone surgery or were excluded from analysis for another reason. Table 5 gives the rate of GON at various angle widths in Mongolians and Singaporeans. The rates of GON were highest in eyes with the narrowest drainage angles, although the small number of subjects in the Singapore cohort with 10° angles and glaucoma meant that the confidence intervals overlapped with other groups.
For Mongolian people, multiple logistic regression demonstrated a significant, independent association between greater age ($p = 0.002$), higher IOP ($p = 0.004$), narrower angle width ($p = 0.016$), and GON. Neither the presence of PAS ($p = 0.88$) nor sex ($p = 0.77$) was significant in this model. Repeating this analysis for Chinese Singaporean people, only male sex ($p = 0.022$) and IOP ($p \leq 0.001$) were significantly associated with PAS, whereas age was not.

**DISCUSSION**

The Shaffer classification scheme requires an examiner to subjectively grade the angle width in degrees, and allocate a grade to one of five categories (0°, 10°, 20°, 30°, and >40°). Angles of 10° and 20° are seen to be synonymous with a risk of closure as “probable” and “possible,” respectively. Our data show that this assumption holds true for east Asian populations, where angle closure glaucoma is seen with greater frequency than in European people. In eyes with 10° angles, PAS were seen in one third of Mongolian people and one fifth of Singaporean people. In eyes with 20°

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**Table 1** Age and sex distribution of subjects

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Mongolia</th>
<th>Singapore</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>40–49</td>
<td>159</td>
<td>262</td>
</tr>
<tr>
<td>50–59</td>
<td>117</td>
<td>153</td>
</tr>
<tr>
<td>60–69</td>
<td>76</td>
<td>81</td>
</tr>
<tr>
<td>70+</td>
<td>36</td>
<td>34</td>
</tr>
<tr>
<td>Subtotal</td>
<td>388</td>
<td>530</td>
</tr>
</tbody>
</table>

**Table 2** Rate of peripheral anterior synechiae according to mean gonioscopic width* in right eyes

| Mean angle width | Mongolia | | Singapore | |
|------------------|----------|----------|-----------|
| 0°               | (100%)   | 16 (31%) | 0         |
| 10°              | (8.5%)   | 2 (0.6%) | 1         |
| 20°              | (2.1%)   | 1        |
| 30°              | (1.7%)   | 0.4%     |
| >40°             | (0.3%)   | 0.4%     |

**Table 3** Rate of peripheral anterior synechiae in angles graded occludable or not occludable in Mongolian and Singaporean people

<table>
<thead>
<tr>
<th>PAS present</th>
<th>Occludable angle</th>
<th>Total OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Mongolian</td>
<td>15</td>
<td>37</td>
</tr>
<tr>
<td>Singapore</td>
<td>13</td>
<td>53</td>
</tr>
</tbody>
</table>

**Table 4** The rate of peripheral anterior synechiae in people with glaucomatous optic neuropathy in Mongolian and Singaporean people

<table>
<thead>
<tr>
<th>GON present</th>
<th>PAS present</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mongolian</td>
<td>5</td>
<td>25</td>
<td>8</td>
<td>878</td>
<td>916</td>
<td>22.0</td>
<td>(6.7, 71.9)</td>
</tr>
<tr>
<td>Singapore</td>
<td>0</td>
<td>46</td>
<td>10</td>
<td>939</td>
<td>995</td>
<td>1.1</td>
<td>(0.1, 19.0)*</td>
</tr>
</tbody>
</table>

*Calculated using a correction for continuity.
Table 5  Rate of glaucomatous optic neuropathy, subdivided according to mean gonioscopic width*

<table>
<thead>
<tr>
<th>Mean angle width</th>
<th>0˚</th>
<th>10˚</th>
<th>20˚</th>
<th>30˚</th>
<th>&gt;40˚</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mongolia Number with GON (95% CI)</td>
<td>100% (21 to 100)</td>
<td>11.8% (5.5 to 23.4)</td>
<td>0.0% (0 to 2.9)</td>
<td>1.1% (0.4 to 2.9)</td>
<td>0.5% (0.1 to 1.9)</td>
<td>1.4% (0.8 to 2.4)</td>
</tr>
<tr>
<td>Singapore Number with GON (95% CI)</td>
<td>100% (21 to 100)</td>
<td>11.8% (5.5 to 23.4)</td>
<td>0.0% (0 to 2.9)</td>
<td>1.1% (0.4 to 2.9)</td>
<td>0.5% (0.1 to 1.9)</td>
<td>1.4% (0.8 to 2.4)</td>
</tr>
</tbody>
</table>

* Mean gonioscopic width calculated by adding Shaffer grade in each of four quadrants and dividing by 4; 0 = 0 in all quadrants, 1 = 0.25–1.25, 2 = 1.5–2.25, 3 = 2.5–3.25, 4 = 3.5–4.

Eyes having previous intraocular surgery and secondary pathology such as iris neovascularisation were excluded.

The Singaporean cohort was selected to include proportionately more elderly subjects than are found in the national population (not using probably proportional to size sampling), and hence the rate of glaucoma does not correspond to a population prevalence.
of an “occludable angle” used by our group and others in epidemiological studies of glaucoma should be reconsidered.

ACKNOWLEDGEMENTS
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