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R J Casson, H S Newland, J Muecke, S McGovern, L M Abraham, W K Shein, D Selva, T Aung

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See end of article for authors' affiliations

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Correspondence to:
Professor R J Casson,
Department of
Ophthalmology & Visual
Sciences, South Australian
Institute of Ophthalmology,
Adelaide University, South
Australia 5000, Australia;
robert.casson@adelaide.
edu.au

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Aim: To determine the prevalence of preglaucomatous angle-closure disease in central Myanmar.
Methods: A population-based survey of inhabitants $\geq$40 years in the Meiktila District was carried out; 2481 subjects were identified, 2076 participated and 2060 underwent gonioscopy of at least one eye. Eyes with angles traditionally described as ''occludable'' were recorded as primary angle-closure suspects (PACS); eyes with PACS and peripheral anterior synechiae (PAS), or an increased intraocular pressure but without primary angle-closure glaucoma, were recorded as primary angle closure (PAC).
Results: The prevalence of PACS in at least one eye was 5.7% (95% CI 4.72 to 6.62); prevalence increased with age and was more common in women (p<0.001). The prevalence of PAC in at least one eye was 1.50% (95% CI 1.47 to 1.53). All participants with PAS had at least 90° of closure (range 90–360°).
Conclusion: The prevalence of preglaucomatous angle-closure disease (PACS and PAC) in this population was 5.7% and 1.5%, respectively. PACS was more common in women, and its prevalence increased with age.

It is estimated that by 2010 primary angle-closure glaucoma (PACG) will be responsible for approximately half the global burden of blindness due to glaucoma,[1] with most of those blinded by PACG residing in Asia.[1] [2] Several recent studies have provided valuable epidemiological information about the prevalence of PACG in certain Asian regions.[3–10] It is evident that the prevalence of PACG is highly region-dependent within Asia; it seems to be particularly common in Mongolian and Chinese eyes and variable across India and Southeast Asia.[4–6] [8–11]

The International Society for Geographical and Epidemiological Ophthalmology (ISGEO) has recently proposed definitions which reserve the term ''glaucoma'' for those with glaucomatous optic neuropathy (GON).[12] Those eyes with iridocorneal angles traditionally described as ''occludable'' have been renamed as primary angle-closure suspects (PACS), and those meeting the criteria for PACS, but with peripheral anterior synechiae (PAS) and without GON, are described as having primary angle closure (PAC). These conditions are considered to represent preglaucomatous stages in the natural history of PACG,[3] [12] and indicate the long-term risk of visual morbidity.[13] [14] Hence, according to this conceptual model, population-based gonioscopic data can provide valuable information about the risk level of PACG within a defined population, and can assist in the implementation of screening and treatment programmes and in the allocation of limited healthcare resources.[15] [16]

Anecdotally, acute angle-closure glaucoma is a common clinical entity with high visual morbidity in central Myanmar (formerly Burma); however, until now, there have been no robust data about the prevalence of angle-closure disease in this region, and gonioscopic findings from Burmese eyes have hitherto been unreported. We conducted a population-based ophthalmic survey in the rural Meiktila District in central Myanmar, with an aim of providing accurate gonioscopic data on this population, including the prevalence of PACS and PAC.

METHODS

The Meiktila Eye Study was a population-based, cross-sectional ophthalmic survey of the inhabitants of rural villages in the Meiktila District of central Myanmar. The study was conducted within the Mandalay Division, encompassing an area of 34 253 km², divided into seven second-order administrative districts of approximately equal size. The township of Meiktila (with a population of approximately 251 000), located at 20°53′N, 95°53′ E, lies centrally in the Meiktila District, and is the only non-agricultural region in this entire district. The district is arbitrarily divided by the Ministry of Health (MOH) into six zones served by a centrally located eye hospital in Meiktila.

Participants were selected using a randomised, stratified, cluster-sampling process. A sampling frame consisting of the list of all villages in the Meiktila District with their populations was obtained from the MOH. For logistical reasons, sampling was restricted to villages within 3 h drive from Meiktila (an area encompassing approximately 80% of the district).

Study population

All people aged $\geq$40 years within each selected village were eligible for inclusion. Healthcare workers from Meiktila Township enumerated the selected villages (and advertised and promoted the survey) before commencement of the survey. Six small villages (one from each zone) and four large villages were enumerated, providing a total sample population of 2481 people, all belonging to the Burman ethnic group.

Data collection

A single survey team conducted the entire study in November 2005. Each team member was assigned specific tasks and was well trained in the appropriate area. All equipment and personnel were transported to each village, and the data collection occurred on site. An ophthalmic history was obtained in the participants' own language, including the occurrence of ocular pain, blurred vision and haloes.
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Table 1 Modified Scheie's grading*

Most posterior angle structure visible	Grade
Nil	0
Schwalbe's line and anterior meshwork	1
Posterior pigmented meshwork	2
Scleral spur	3
Ciliary band	4

*Each quadrant was graded using both static and dynamic gonioscopy.

Table 3 Grading of angle in each quadrant in the left eye (n = 2034)

Angle grading	Superior quadrant (%)	Nasal quadrant (%)	Inferior quadrant (%)	Temporal quadrant (%)
0	2.7	2.3	2.2	2.6
1	11.0	10.5	11.3	12.4
2	15.9	20.2	20.3	20.9
3	62.2	59.9	58.7	57.5
4	8.2	7.1	7.6	6.6

Intraocular pressure (IOP) was measured by one observer (TA) with a Goldmann applanation tonometer (calibrated at each site; Haag-Street, Koniz, Switzerland), and anterior segment examination was performed at the slit lamp (Model SL-3C, Topcon, Tokyo, Japan). Gonioscopy was performed by two experienced gonioscopists (RJC and SM) using a Sussman goniolens. As several previous studies[4–6 16 17] had used the Shaffer grading system,[18] based on the angle of iris insertion, the gonioscopists conducted preliminary training with this system at the Royal Adelaide Hospital, Adelaide, Australia; however, this system seemed unfamiliar, and agreement about the angle of iris insertion was considered unsatisfactory ($\kappa = 0.45$). Hence, a modified Scheie system[19] (table 1), based on the structures visible gonioscopically, which is almost universally used to define "occludability" and was used routinely by the gonioscopists, was used to grade the angle (table 1), with excellent agreement ($\kappa = 0.78$). Static gonioscopy was performed in dim illumination, with minimal pressure on the cornea, using a short slit beam; dynamic gonioscopy was then performed. Pupils were then dilated with tropicamide 1% and phenylephrine 2.5%; however, eyes with PACS were dilated with tropicamide 0.5% only and kept under observation for 4 h; if not possible, they were not dilated; eyes with PAC were not dilated. Optic disc and retinal examination were performed by two experienced ophthalmologists (HSN and JM), using a 78D lens and reference to standard disc images. The vertical cup:disc ratio (VCDR) and the presence of focal notching were recorded. The agreement between the two ophthalmologists was good for determining the VCDR ($\kappa = 0.72$).

Statistics
Prevalence rates were calculated as ratio estimates, using appropriate weights for each of the sampled villages. All prevalence estimates were performed using SAS V.9.1. Villages were randomly selected; hence, point prevalences are unbiased. χ^2 test and Fisher's exact test were used to compare proportions in the PACS and PAC groups, respectively.

Diagnostic definitions
The definitions of PACS and PAC were based on the definitions suggested by the ISGEO.[12] If $\leqslant 90^\circ$ of posterior trabecular meshwork was visible with static gonioscopy, the eye was recorded as occludable and designated as PACS. PAC was defined

Table 2 Grading of angle in each quadrant in the right eye (n = 2037)

Angle grading	Superior quadrant (%)	Nasal quadrant (%)	Inferior quadrant (%)	Temporal quadrant (%)
0	2.5	2.4	2.5	2.8
1	11.5	11.9	11.2	10.9
2	16.2	21.7	21.5	20.6
3	61.7	57.6	58.4	59.4
4	8.3	6.4	6.44	6.3

as any eye with PACS and PAS and/or increased IOP (>97.5th percentile for the population ($\geqslant 22$ mm Hg in this study)), and/or iris whorling or stromal atrophy, but without any GON. PAS was defined as an area of iridotrabecular contact which could not be broken during dynamic gonioscopy. The number of clock hours of PAS was recorded. PAS in eyes with previous intraocular surgery was recorded as surgically induced PAS and not included in this report. PAS in the presence of GON or postcongestive acute glaucoma was not included in this analysis.

Ethics
The Meiktila Eye Study was approved by the MOH in Myanmar, and had ethical approval from the Royal Adelaide Hospital Ethics Committee. Consent for participation was obtained from the head of each village before commencement of the survey, and written, informed consent, in the participants' own language, was obtained from all willing participants. The study was conducted in accordance with the Declaration of Helsinki.

RESULTS
A total of 2381 subjects were eligible, and 2076 were examined (836 males, 1240 females; participation rate 87.2%). Gonioscopy could be performed in both eyes of 2011 subjects, and in at least one eye of a further 49 subjects. The distribution of the angle grading in each quadrant for the right and left eyes is shown in tables 2 and 3, respectively. For each grade, there were no significant differences between the numbers in each quadrant. A grade 3 angle (scleral spur visible) was the commonest angle configuration; however, posterior pigmented meshwork was not visible during static gonioscopy in at least one quadrant in approximately 10% of the eyes.

Primary angle-closure suspect
There were 117 participants (91 women, 26 men) with PACS in at least one eye. The prevalence of PACS in at least one eye, allowing for the study design, was 5.7% (95% CI 4.72 to 6.62). The mean (SD) age of this group was 59.8 (10) years. The mean (SD) IOP was 14.4 (3.64) mm Hg in the right eye and 14.5 (3.14) mm Hg in the left eye. The mean (SD) VCDR was 0.3
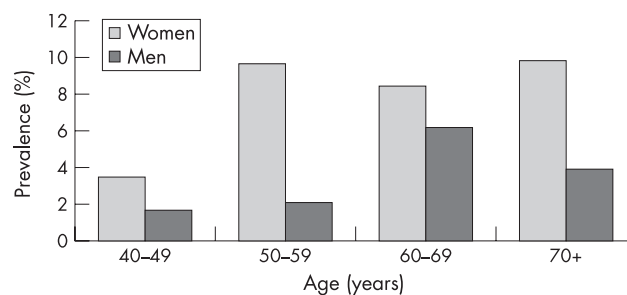
Figure 1 Prevalence of primary angle-closure suspects by gender in different age groups.
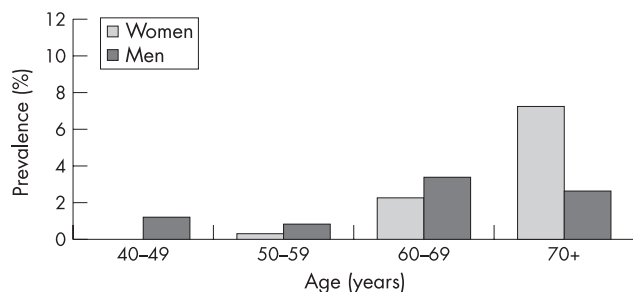
Figure 2 Prevalence of primary angle closure by gender in different age groups.

(0.15) in both eyes. Figure 1 shows the prevalence of PACS by age and gender. PACS was significantly more common in those ≥50 years of age (p<0.001), and was more common in women (p<0.001).

Primary angle closure

There were 31 participants (16 women and 15 men) with PAC in at least one eye. The prevalence of PAC in at least one eye, allowing for the study design, was 1.50% (95% CI 1.47 to 1.53). In all, 9 (29.03%) participants had an IOP of ≥22 mm Hg, 21 (67.7%) had PAS and 4 (12.9%) had both. The VCDR in both eyes was 0.4 (0.16). The mean (SD) age was 67.12 (14.38) years. The prevalence of PAC by gender and age is given in fig 2. There were significantly more women than men with PAC (aged ≥70 years; p = 0.032; Fisher's exact test).

Peripheral anterior synechiae

All of the 21 participants with PAS had at least 90° of closure (range 90–360°); 15 had PAS involving the superior angle. Only one subject with PAS had symptoms. There were five participants with PAS who did not meet the criteria for PACS (because >90° of trabecular meshwork was visible), but all had visible posterior meshwork for <180°. Hence, in the current system based on ISGEO criteria, they were unclassifiable (because PAC requires the presence of an occludable angle), but logically would be recorded as PAC.

Discussion

The prevalence of narrow angles is higher among East Asians than among Europeans; this tendency persists despite migration, suggesting a genetic influence.[20][21] Alsbirk[22] proposed that the high prevalence of PACG in the Greenlandic Inuit was related to a cold climate evolutionary modification of the eye, with shallower anterior chambers resisting corneal freezing.

Similar results were found among Inuits in northwest Alaska.[16] The high prevalence of PACG in Mongolia[6] and China,[23] and the fact that the Inuits are derived from this region,[24] suggests that this evolutionary modification first developed in northeast Asia, after human expansion northwards into this region towards the end of the last ice age.[25] The high prevalence of PACG in people of Southeast Asian extraction implies a subsequent reverse migration into southern regions. In fact, there is archaeological evidence to support this "Out of Northeast Asia" theory for PACG.[26] However, Y-chromosome data indicate that the northern Asian ancestry is very unevenly dispersed through the Southeast Asian region.[27] Hence, although an understanding of the migration patterns of early man out of Northeast Asia may help predict the regional prevalence of narrow angles, it is likely that only robust population-based ophthalmic studies can provide accurate data.

Table 4 compares the prevalence of PACS and PAC in several population-based Asian studies. The prevalence of preglaucomatous angle-closure disease in the current study was similar to that found in other south and central East-Asian regions.

Gonioscopy is indispensable in the management of glaucoma, and formed an integral part of the current study. Although we were cognisant of the importance of consistency among epidemiological studies, to improve accuracy in our hands, we elected to use a modified Scheie-type classification based on the angle structures seen gonioscopically. Given that this system is universally used to assess occludability, these data should be comparable with similar studies (table 4). However, we acknowledge that comparison of the angle gradings with studies that have used the Shaffer system may be less valid. Foster et al[28] have reported that PAS are often observed in eyes that have >90° of visible posterior meshwork, suggesting that the current definition of PACS is too stringent. We detected five participants with PAS who did not meet the criteria for PACS. It seems likely that there is overlap between Shaffer grades 1 and 2 and grade 1 in our system. Presently, there is no consensus on the definition of PAS in epidemiological studies, and it is possible that we under-reported this condition; however, rates of PAC were comparable with other similar population-based studies (table 4). Previous studies have reported that the superior angle is initially affected by PAS[29–31]; our results tend to support this observation.

A salient finding was the extent of PAS in asymptomatic affected eyes. The pathogenesis of this form of PACG is unclear but is likely to be multifactorial, involving pupillary block, anterior ciliary processes and anterior lens position.[3] There is evidence that non-pupillary block mechanisms are involved in many cases of PACG,[3] particularly in the eyes of Asians,[3] and in most cases iridotomy does not prevent the progression of established PACG.[32] However, the efficacy of iridotomy at an

Table 4 Prevalence rates of preglaucomatous angle-closure disease in population-based studies

Author (year)	Location	Number: of patients in age group	Age group	PACS (%)	PAC (%)
Arkell et al[16] (1987)	Northwest Alaska, USA	267	≥50	16.5	NR
Salmon et al[17] (1993)	Mamre, South Africa	987	≥40	*6.7	NR
Foster et al[6] (1996)	Hovsgol, Mongolia	942	≥40	3.3	2.0
Dandona et al[10] (2000)	Andhra Pradesh, India	1399	≥30	1.4	NR
Foster et al[4] (2000)	Tanjong Pagar, Singapore	1232	≥40	3.3	1.4
Vijaya et al[7] (2006)	Chennai, India	3924	≥40	†6.3	0.7
Bourne et al[5] (2003)	Bangkok, Thailand	710	≥50	10.1	3.1
Present study	Meiktila, Myanmar	2011	≥40	5.7	1.5

NR, not reported; PAC, primary angle closure (PACS and an intraocular pressure >97.5th centile or peripheral anterior synechiae, but no glaucomatous optic neuropathy (GON)); PACS, primary angle-closure suspect (posterior meshwork visible for <90° and excluding those with PAC and GON.
*Shaffer grade 1 angles but no glaucoma.
†Posterior trabecular meshwork visible for <180°.

even earlier stage, prior to the development of PAS and PACG, is unclear. A study investigating iridotomy in a Mongolian population with occludable angles will help determine the efficacy of iridotomy in an early stage of the disease in an Asian population.[33] The current study and others[4][5][7] have shown that the prevalence of PACS is much higher than PAC. Thomas *et al*[14] reported that the 5-year incidence of conversion from PACS to PAC was 22%, and that of conversion from PAC to PACG was 29%.[13] They were unable to identify any features that predicted progression to glaucoma.

In conclusion, the prevalence of preglaucomatous angle-closure disease (PACS and PAC) in this Burmese population was 5.7% and 1.5%, respectively. PACS was more common in women, and its prevalence increased with age. Further research investigating the factors which drive progression in some eyes, and not in others, is needed, and understanding the mechanistic profile in different stages of the disease would assist the development of treatment strategies.

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Authors' affiliations
R J Casson, H S Newland, J Muecke, S McGovern, L M Abraham, D Selva, South Australian Institute of Ophthalmology, Department of Ophthalmology & Visual Sciences, Adelaide University, Adelaide, South Australia
W K Shein, Trachoma Control and Prevention Programme, Meiktila Eye Hospital, Meiktila, Myanmar
T Aung, Yangon Eye Hospital, Yangon, Myanmar

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