Angle Closure in the Namil Study in Central South Korea

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Objective: To assess the prevalence and associated risk factors of angle closure in a defined population as part of the Namil Study.

Methods: In this cross-sectional epidemiologic study for residents aged 40 years or older in Namil-myon, a rural area in central South Korea, the examination included slitlamp biomicroscopy, applanation tonometry, gonioscopy, autorefraction, fundus photography, corneal thickness measurement, visual field test with frequency doubling technology, and anterior chamber depth (ACD) and axial length (AL) measurements with partial coherence interferometry. Standard automated field test and optical coherence tomography or scanning laser polarimetry were performed to confirm the glaucomatous visual field/optic disc damage. Angle closure included primary angle-closure suspect (PACS), primary angle closure (PAC), and primary angle-closure glaucoma (PACG). Definitions of PACS, PAC, and PACG were based on the recommendations from the International Society for GEOgraphical & Epidemiological Ophthalmology.

Results: Among the 1426 individuals enrolled for the assessment, with exclusion of cataract surgery, the prevalence rates of PACS, PAC, PACG, and overall angle closure in at least 1 eye were 2.0% (95% CI, 1.3%-2.8%), 0.5% (95% CI, 0.1%-0.9%), 0.7% (95% CI, 0.3%-1.1%), and 3.2% (95% CI, 2.3%-4.2%), respectively. Multivariate analysis found that older age (odds ratio [OR], 1.8797; 95% CI, 1.4624-2.4162), shallower ACD (OR, 0.9982; 95% CI, 0.9977-0.9987), and shorter AL (OR, 0.9978; 95% CI, 0.9969-0.9988) (P < .001 for each) were significantly associated with angle closure.

Conclusions: The overall prevalence of angle closure was 3.2% in the present study. On the basis of these findings, increasing age, shallower ACD, and shorter AL appear to be associated with angle closure.

Trial Registration: clinicaltrials.gov Identifier: NCT00727168

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HE PREVALENCE OF ANGLE closure varies according to race and geographic region. The published prevalence rates are the highest among the Eskimo population1,2 and the lowest for the white population3-5; Asians, including the Chinese,6 Mongol,7 Thai,8 Indian,9,10 Sri-Lankan,11 and Japanese12 populations, have rates between those levels.

Recent epidemiologic studies adopting the International Society of GEOgraphical & Epidemiological Ophthalmology (ISGEO) definition13 have demonstrated that female sex, old age, and shallow anterior chamber depth (ACD) are associated risk factors for primary angle-closure suspect (PACS), primary angle closure (PAC), and primary angle-closure glaucoma (PACG).9,10 Increased intraocular pressure (IOP), female sex, increased age, and diabetes mellitus are associated risk factors for PAC and PACG.9,10 Increasing age, decreasing axial length (AL), decreasing ACD, and nuclear cataract are associated risk factors for PACS and PAC.15 Finally, old age, family history, high IOP, and constipation are associated risk factors for PACG.10

Because of insufficient population-based prevalence studies in Korea, there is little information on the prevalence and associated risk factors of angle closure in Korea. The Namil Study,17 a population-based prevalence study in Korea, was initiated by the Korean Glaucoma Society, and the results concerning primary open-angle glaucoma (POAG) have been published. As a part of the Namil Study, the prevalence and associated risk factors of angle closure were evaluated in a rural Korean population with the use of the ISGEO definition, and the results were compared with data from other Asian countries.
The participants included in this study were the same as those who participated in the previously reported Namil Study. This study was approved by the institutional review board of Chungnam National University Hospital. The work was performed in accordance with the Declaration of Helsinki. Of a total of 310+ residents of Namil-myon (an inland, low-mountainous, rural, and agricultural area of 47.14 km² located in central South Korea), the number of inhabitants aged 40 years or older was 1928. The 1532 persons who participated in the Namil Study represented a response rate of 79.5%. The details of the screening examination, definitive examination, and evaluation of test results are described in the previous Namil Study report. The screening examination, performed by a trained technician, included a medical and ophthalmologic history, autorefraction, fundus photography, corneal thickness measurement, visual field test with frequency-doubling technology, and ACD and AL measurements with partial coherence interferometry. The slitlamp examination, IOP measurements with the Goldmann application tonometer, binocular optic disc evaluation, and gonioscopy were performed by a glaucoma specialist.

The definitive examinations for glaucomatous visual field/optic disc damage included a visual field test with a visual field analyzer (SITA Standard 30-2; Humphrey Field Analyzer HFA II 720i; Carl Zeiss Meditec) or scanning laser polarimetry (GDxVCC; Carl Zeiss Meditec). The same definition for the glaucomatous optic neuropathy (GON) and visual field damage was used in this study as in the previous report of the Namil Study for POAG. Three separate reading committees evaluated the test results. Each reading committee consisted of glaucoma specialists who were not involved in the examination of the participants.

The angle status was initially evaluated using a Goldmann-type gonioscopic lens in all participants. An occludable angle was defined as an angle with less than 90° of posterior trabecular meshwork visible. The visibility of the posterior trabecular meshwork and angle width was evaluated in primary gaze without digital pressure on the lens. Peripheral anterior synchiae was defined as an iridocorneal contact area that could not be detached during gonioscopy. If a satisfactory examination could not be done with the Goldmann-type lens, a 4-mirror lens was used. Angle closure was classified into 1 of 3 clinical subtypes, using the definitions reported by the ISGEO.

1. Primary angle-closure suspect was defined as an eye with an occludable angle and IOP 21 mm Hg or less without peripheral anterior synchiae or glaucomatous change of the optic disc/visual field. Primary angle closure was defined as an eye with any degree of peripheral anterior synchiae or with an occludable angle accompanied by an elevated IOP (>21 mm Hg) and/or iris ischemia (iris whirling and stromal atrophy) but without glaucomatous damage documented on the optic disc/visual field test. In aphakic/pseudophakic eyes, the presence of peripheral anterior synchiae, previous laser iridotomy, and/or iris ischemia was considered a diagnostic clue of PAC; any iris changes related to cataract surgery were not regarded as the diagnostic clue of PAC. Primary angle-closure glaucoma was defined as an eye with glucomatous damage to the optic nerve/visual field in the presence of PAC.

In this study, we excluded individuals who had undergone bilateral cataract extraction if both eyes did not have any diagnostic clue for angle closure. The prevalence of angle closure was calculated based on an individual rather than an eye. If a participant had one eye with PACS and the other eye with PACG, he or she was categorized as having the severe subtype, PACG. By the same token, if one eye had PAC and the contralateral eye had PACS, the person was categorized as having PAC.

The assessment of the risk factors and biometric data was based on an eye rather than an individual. Commercial software (SSPS 12.0K; SPSS Inc) was used to analyze differences among the groups using the unpaired 2-tailed t test, analysis of variance, and χ² test. The Bonferroni test for multiple comparisons was used when necessary. Comparison was made between nonglaucomatous eyes and angle-closure eyes when risk factors were estimated and biometric data were analyzed; values in aphakia/pseudophakia were excluded from the ACD evaluation. To minimize the intereye correlation of participants, generalized estimating equation analysis with an unstructured covariance was used to evaluate associated risk factors for angle closure, using commercial software (SAS 9.2; SAS Institute Inc). We performed univariate generalized estimating equation analysis for all predictors, including sex, age, smoking, diabetes mellitus, hypertension, family history of glaucoma, IOP, spherical equivalent, hyperopia, ACD, AL, and corneal thickness. We fitted a multivariate generalized estimating equation model, using all variables that were statistically significant at P < .05 in univariate analyses.

Of the 1532 participants in the Namil Study, 170 individuals (11.1%) underwent cataract surgery in at least 1 eye. Of those with pseudophakia/aphakia, we excluded 106 individuals (6.9%) who underwent bilateral cataract extraction because both eyes did not have any evidence of angle closure. We included 61 persons with unilateral cataract extraction and included 3 with bilateral cataract extraction in whom at least 1 eye had a clue for angle closure. Therefore, 1426 participants were evaluated for the prevalence of angle closure. There were 625 men (43.8%) and 801 women (56.2%), and the distribution was similar to that of the total population of Namilmyon (male, 44.2%; female, 55.8%).

Overall angle closure in at least 1 eye was evident in 46 participants, with a prevalence of 3.2% (95% CI, 2.3%-4.2%) (Table 1). Twenty-nine participants (8 men, 21 women) had PACS in at least 1 eye, and the prevalence was 2.0% (95% CI, 1.3%-2.8%) (Table 1). There were 7 individuals (1 man, 6 women) with PAC in at least 1 eye. The prevalence of PAC was 0.5% (95% CI, 0.1%-0.9%). Ten participants (4 men, 6 women) were identified as having PACG in at least 1 eye, and the prevalence rate was 0.7% (95% CI, 0.3%-1.1%).

Before this survey, no participant had a diagnosis of PACS. One with PAC underwent combined cataract and glaucoma surgery and received β-blocker therapy in 1 eye, 1 participant with phakic PAC underwent surgical iridectomy in both eyes, and 1 participant with pseudophakic PAC underwent laser iridotomy in both eyes. One participant with pseudophakia had PACG and had undergone laser iridotomy in both eyes.

Two participants with PACS had a visual acuity of less than 20/400 (World Health Organization criterion for blindness) in at least 1 eye. However, the reason for decreased vision in these 2 individuals appeared not to be related to glaucoma because no participant with PACG had a visual acuity of less than 20/400.
Mean age, ACD, and AL were significantly different between angle-closure eyes and nonglaucomatous eyes (all P < 0.05, t test). However, those variables were not significantly different among the subgroups of angle closure (Table 2).

Women had a shorter ACD vs men (mean [SD], 2.98 [0.34] mm vs 3.12 [0.35] mm; P < 0.001, t test) and AL (23.08 [0.98] mm vs 23.60 [0.78] mm; P = 0.01, t test) in nonglaucomatous eyes. In angle-closure eyes, ACD tended to be shallower in women than men, although the difference did not reach a level of significance (2.39 [0.17] mm vs 2.51 [0.25] mm; P = .08, t test); however, AL was significantly shorter in women (22.49 [0.62] mm) than in men (23.25 [0.66] mm; P < .001, t test) (Table 3).
Sex, age, spherical equivalent, ACD, and AL were significantly different in univariate analysis for the associated factors of overall angle closure. In multivariate analysis, older age (odds ratio [OR], 1.8797; 95% CI, 1.4624-2.4162), shallower ACD (OR, 0.9982; 95% CI, 0.9977-0.9987), and shorter AL (OR, 0.9978; 95% CI, 0.9969-0.9988) were also significant (P < .001 for each) (Table 4).

After exclusion of individuals with previous bilateral cataract extraction if both eyes did not have any evidence of angle closure, the prevalence rates of PACS, PAC, and PACG increased when compared with the rates including cataract surgery cases (Table 5). The prevalence of overall angle closure increased from 3.0% before excluding cataract surgery cases to 3.2% after excluding cataract surgery cases.

Therefore, the prevalence of overall angle closure may be about half that of the overall POAG prevalence, including suspect and ocular hypertension. However, the prevalence of POAG was 3.5% and that of PACG was 0.7%. Thus, the prevalence of POAG was 5 times higher than that of PACG in Namil-myon, Korea.

Regarding the proportions of POAG to PACG in the Asian glaucoma prevalence studies based on the ISGEO classification, the ratio was 0.8:1 in the Meiktila Eye Study in Myanmar18; nearly equal in a population-based survey in Kailu County, Inner Mongolia, northern China19; 1.4:1 in Liwan in China6; 2.6:1 in the Beijing Eye Study in China20; 2.6:1 in Rom Klao in Thailand8; and 3:1 for Chinese in the Tanjong Pagar study.21 Our study showed a ratio of 5:1 and the Japanese Tajimi Study13 reported a ratio of 6.5:1. In contrast, the ratio was more than 10:1 in the West Bengal Glaucoma Study22 and 24:1 for Malay participants in the Singapore Malay Eye Study.23

Table 6 reports the prevalence rates of PACS, PAC, and PACG in selected Asian population-based studies.6-13,16,18,19,21-25 Concerning the ratio of POAG to PACG and the prevalence, angle closure appears to be more frequent in China and less frequent in West Bengal and in Malay people (Singapore Malay Eye Study) than in our study. Primary angle closure was also lower in preva-
Table 6. Prevalence of Angle Closure in Selected Population-Based Studies in Asia

<table>
<thead>
<tr>
<th>Location</th>
<th>Age Limit, y</th>
<th>PACS (% 95% CI)</th>
<th>PAC (% 95% CI)</th>
<th>PACG (% 95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Asia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hövsgöl, Mongolia2</td>
<td>40</td>
<td>6.4 (4.3-8.5)</td>
<td>...</td>
<td>1.4 (0.1-2.2)</td>
</tr>
<tr>
<td>Livotan, Southern China4</td>
<td>50</td>
<td>10.2 (8.6-11.8)</td>
<td>2.4 (1.6-3.1)</td>
<td>1.5 (0.9-2.1)</td>
</tr>
<tr>
<td>Kalu, Northern China19</td>
<td>40</td>
<td>5.12 (4.52-5.72)</td>
<td>1.20 (0.90-1.50)</td>
<td>1.74 (1.39-2.10)</td>
</tr>
<tr>
<td>Bin, Northeast China16</td>
<td>40</td>
<td>4.68 (4.54-4.81)</td>
<td>1.33 (1.24-1.42)</td>
<td>1.57 (1.47-1.67)</td>
</tr>
<tr>
<td>Handan, Northern China24</td>
<td>40</td>
<td>10.4 (9.6-11.2)</td>
<td>1.5 (1.2-1.8)</td>
<td>0.5 (0.3-0.7)</td>
</tr>
<tr>
<td>Tajimi, Japan23</td>
<td>40</td>
<td>...</td>
<td>0.5 (0.26-0.74)</td>
<td>0.6 (0.35-0.91)</td>
</tr>
<tr>
<td>Namil, Korea</td>
<td>40</td>
<td>2.0 (1.3-2.8)</td>
<td>0.5 (0.1-0.9)</td>
<td>0.7 (0.3-1.1)</td>
</tr>
<tr>
<td>South Asia</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Chennai, South India, rural10</td>
<td>40</td>
<td>6.27 (5.51-7.03)</td>
<td>0.71 (0.45-0.98)</td>
<td>0.87 (0.58-1.16)</td>
</tr>
<tr>
<td>Chennai, South India, urban11</td>
<td>40</td>
<td>7.24 (6.38-8.02)</td>
<td>2.75 (2.01-3.49)</td>
<td>0.88 (0.60-1.16)</td>
</tr>
<tr>
<td>Andhra Pradesh, South India9</td>
<td>40</td>
<td>2.0 (1.5-2.3)</td>
<td>0.3 (0.1-0.5)</td>
<td>0.9 (0.6-1.2)</td>
</tr>
<tr>
<td>West Bengal, East India22</td>
<td>50</td>
<td>...</td>
<td>...</td>
<td>0.23a</td>
</tr>
<tr>
<td>Dhaka, Bangladesh25</td>
<td>40</td>
<td>...</td>
<td>...</td>
<td>0.4 (0.2-0.8)</td>
</tr>
<tr>
<td>Kandy, Sri Lanka12</td>
<td>40</td>
<td>2.35 (0.0-4.7)</td>
<td>1.86 (0.6-3.1)</td>
<td>0.57 (0.0-1.2)</td>
</tr>
<tr>
<td>South-East Asia</td>
<td></td>
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<tr>
<td>Tanjong Pagar, Singapore, Chinese people27</td>
<td>40</td>
<td>6.3 (4.9-7.6)</td>
<td>2.2 (1.4-3.1)</td>
<td>0.8 (0.4-1.2)</td>
</tr>
<tr>
<td>Singapore Malay Eye Study, Malay people23</td>
<td>40</td>
<td>...</td>
<td>...</td>
<td>0.12 (0.10-0.14)</td>
</tr>
<tr>
<td>Meiktila, Myanmar18</td>
<td>40</td>
<td>...</td>
<td>...</td>
<td>2.5 (1.5-3.5)</td>
</tr>
<tr>
<td>Rom Kao, Thailand4</td>
<td>50</td>
<td>10.1 (7.9-12.8)</td>
<td>3.1 (1.9-4.7)</td>
<td>0.9 (0.3-1.9)</td>
</tr>
</tbody>
</table>

Abbreviations: PAC, primary angle closure; PACG, primary angle-closure glaucoma; PACS, primary angle-closure suspect.
aThe 95% CI was not provided in Raychaudhuri et al.22

In our study, except for that of the Andhra Pradesh Eye Disease Study,9 and was similar to that in the Tajimi Study.13 With regard to PACS, the prevalence in China, India, and Thailand also appears to be higher than in our study. The prevalence of PACS in the present study was relatively lower than in other Asian populations and similar to those of the studies of Andhra Pradesh, South India,9 and Kandy, Sri Lanka.12

The Beijing Eye Study20 documented that 2% of the participants were aphakic/pseudophakic, although the researchers did not calculate prevalence according to the lens status. On the other hand, only those with phakia were included in the analysis of the angle-closure prevalence in the Kandy Eye Study.12 Calculating the prevalence of angle closure including individuals with previous cataract extraction can confound the prevalence result because increasing rates of cataract surgery may be related to the incidence of angle closure.26,27

We believe that the prevalence obtained after excluding cataract surgery cases would be closer to reality. Nevertheless, considering the prevalence of angle closure after the exclusion of cataract surgery cases as a real prevalence may also be an oversimplification of reality because we do not know how many individuals with previous cataract surgery had angle closure, especially PACS, before surgery and how cataract surgery prevents angle closure.

After excluding cataract extraction cases, age- and sex-standardized prevalence could not be calculated because we did not know how many nonresponders underwent cataract extraction. Thus, only the crude prevalence rate was calculated (Table 5).

The Meiktila Eye Study15 and the Kandy Eye Study12 showed that women with open angles had significantly shorter ACD compared with men; however, the difference in ACD in women with angle closure was not significant from that in men. We found similar findings in our study. Casson et al13 postulated that angle closure may be related to the shorter ACD in women and that men with a shallow ACD may have a risk similar to women with a shallow ACD.

Age and ocular biometry were not significantly different among the subgroups of angle closure (PACS, PAC, and PACG), although those were different between non-glaucomatous eyes and angle-closure eyes. The Chennai Glaucoma Study10 and the Handan Eye Study24 showed similar results. Therefore, factors other than ocular biometry may play a role in the development of more severe forms of angle closure.

In our study, blindness related to PACG was not identified. This finding is in contrast to other population-based studies in which blindness was frequent with respect to PACG.6,7,9,21,24 In our study, the number of participants with PACG was small (n=10). A larger population is needed to elucidate the relationship between blindness and PACG in Korea. Blindness associated with PACG might be preventable if there is easy access to the medical care system. The higher incidence of cataract surgery in our study may imply easy access to ophthalmic medical care in the Namil-myon area.

Presently, older age, shallower ACD, and shorter AL were associated with angle closure, which is in line with previous population-based studies.9,10,12,15,30,24 In our study, sex and hyperopia were significant risk factors with univariate analysis but not with multivariate analysis, suggesting that their effects are in part mediated by other variables in our models, such as AL and ACD. Most previous studies9,10,12,24 have reported female sex to be a risk factor for angle closure, although some studies15,16 did...
not show such a statistically significant female predominance in angle closure. Hyperopia may be related to the development of PACG.\(^2\) However, recent population-based studies\(^9,10,12\) in southern India and Sri Lanka did not demonstrate such a relationship with hyperopia and angle closure. Therefore, further studies are needed to clarify the relationship of sex or hyperopia with prevalence of angle closure in Korea.

In summary, our study shows that the prevalence rates of PACS, PAC, and PACG in at least 1 eye were 2.0\%, 0.5\%, and 0.7\%, respectively, and the overall prevalence of angle closure in at least 1 eye was 3.2\%. In addition, increasing age, shallower ACD, and shorter AL were associated with angle closure in men and women aged 40 years or older from Namil-myon, central South Korea.

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