

Rate of Visual Field Progression in Primary Open-angle Glaucoma and Primary Angle-closure Glaucoma

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To estimate the rate of visual field progression in primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG), we reviewed the medical records of POAG and PACG patients who had a minimum of 5-year longitudinal Goldmann visual field data. I4e and I2e isopters were quantified using grid systems. The rate of change was calculated from the slope of a linear fit to a series of average visual field scores. Twenty-three eyes of POAG patients and 25 of PACG patients were studied. The rate of visual field score change was $-2.00 \pm 2.0\%$ per year in the PACG group, and $-0.81 \pm 1.0\%$ per year in the POAG group. In these two patient groups, who were on conventional treatment at two referral hospitals, better visual field on initial presentation yielded faster progression in the POAG group, while the higher average of highest intraocular pressure in each year during follow-up was related to faster progression in the PACG group.

Key words: angle-closure glaucoma, intraocular pressure, Goldmann perimeter, open-angle glaucoma, rate of progression, visual field

INTRODUCTION

Primary open-angle glaucoma (POAG) is characterized by an open iridocorneal angle and progressive optic disc cupping with or without a resultant visual field loss. In contrast, primary angle-closure glaucoma (PACG) is characterized by a closed or narrow iridocorneal angle that interfere with the aqueous efflux, increased intraocular pressure

(IOP), and the resultant optic disc cupping with or without relevant visual field defect. The clinical course of visual progression for these two conditions progresses slowly when the patient is treated properly, so it can take several months to years to detect progressive optic disc damage or visual field loss, although there is some exception in case of acute angle closure glaucoma attack. In general, long-term longitudinal follow-up is needed to determine the rate of visual field decline in both types of glaucoma. However, the equipment and strategy for visual field tests have been continuously changing through the development of new technology. An objective comparison and statistical analysis between data from different types of equipment is difficult, and a comparison of data from the same equipment may be difficult due to frequent changes

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in test strategy in some perimeters. Furthermore, the effect of cataract on the visual field also needs consideration since cataract is frequently developed during long-term follow-up in the elderly, who are most prone to be affected by glaucoma. Due to these limitations, it is not easy to find a satisfactory study on the rate of visual field loss in glaucoma patients. Many studies on visual field progression determined the rate of progression by grading the visual field defect, which can be quite arbitrary. Also, most studies were limited to patients with open angle glaucoma, while studies for patients with PACG, which is prevalent in Asians including Koreans, are rare.

In this study, the Goldmann perimeter was used to examine the progression of visual field loss in glaucoma patients. It has been used as the standard perimeter since the 1940's, with few technical modifications, and the same Armaly-Drance strategy was employed over the entire study period so that longitudinal comparison under the same conditions is relatively easy.^{1,2} Nonetheless, statistical analysis of data from Goldmann perimetry is difficult since these data are not expressed in numeric value. Thus, the manual grid systems by Esterman et al³ and Kwon et al⁴ were used to quantify the results. A simple linear regression analysis was then performed to determine the rate of visual field progression, which was analyzed, along with various clinical factors obtained from the subject patients, to find the factors affecting the rate of visual field loss.

MATERIALS AND METHODS

The medical records of the patients who had been treated for POAG or PACG at Chungnam National University Hospital and Kyungpook National University Hospital from 1986 to 2003 were analyzed retrospectively. The subjects were selected according to the following criteria. (1) Diagnosis of POAG was defined by an age of onset 40 years or older, a normal appearing iridocorneal (open) angle, a peak IOP of higher than 21 mmHg, characteristic glaucomatous optic disc cupping or increased cupping during follow-up, and changes around the disc (nerve fiber layer defect or peripapillary splinter hemorrhage) with or without the characteristic visual field loss.⁴ (2) Diagnosis of PACG was defined

by a peak IOP of higher than 21 mmHg, a narrow or closed iridocorneal angle (Grade C or narrower by the Spaeth classification, or a peripheral anterior chamber depth less than 1/4 corneal thickness by the van Herick classification) by more than 180° around the entire angle, and characteristic optic disc cupping or increased cupping during follow-up with or without any characteristic glaucomatous visual field loss. Patients who experienced an acute angle-closure glaucoma attack with increased IOP higher than 50 mmHg were also included, even if they had no optic disc or visual field change at the initial visit. (3) Among the patients who satisfied the previously stated criteria, those who had longitudinal visual field data from a minimum follow-up of 5 years with Goldmann visual field test were included. The exclusion criterion was any ocular disease other than POAG, PACG and cataract. However, patients with moderate or severe cataract having a visual acuity of worse than 0.4 at the beginning of the study were included. Patients who could not be followed up continuously and those who refused to undergo recommended treatment were also excluded.

Goldmann visual fields were quantified using the manual grid template systems. Among the various stimulus targets, the scores of I4e and I2e isopters were used because the other stimulus targets were not always completely tested. The grid template for the I4e isopter was adapted from the visual field scoring system originally described by Esterman.³ The small grid template for the I2e isopter, which represents a central field of 35°, was adapted from Kwon et al.⁴ Esterman's grid was made of 100 dots distributed in different densities, weighted by the importance of the area, throughout the normal field range. The grid template for the I2e isopter was made of 100 dots distributed within the central 35°, and it was weighted toward the center (Fig. 1). The grid template on a transparent film was overlaid on each visual field, and the dots that fell within each isopter were counted. The average scores of the I4e and I2e isopters were used as the average field scores. The average field scores ranged from 0 (total loss in the I4e and I2e isopters) to 100 points (normal, full field), so that the score was expressed as a percentage of the normal field.

Pertinent clinical information was gathered before

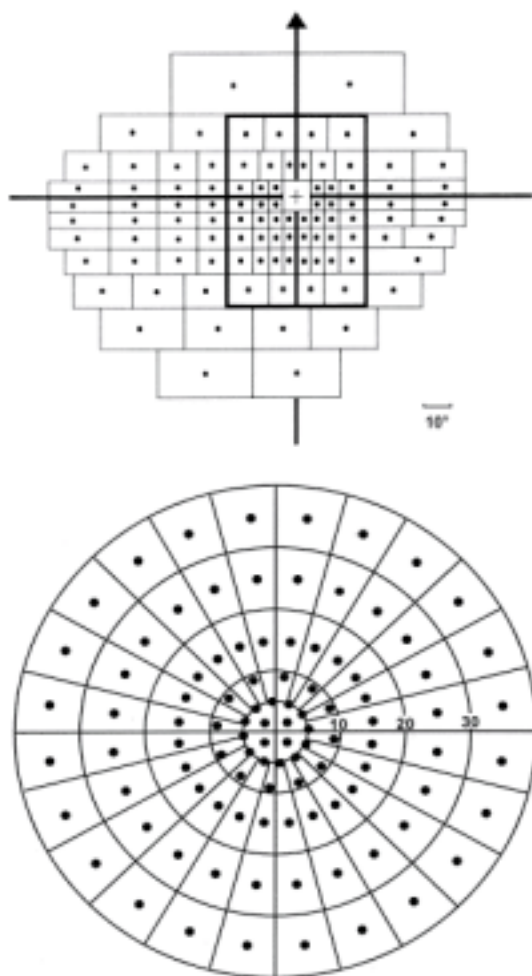


Fig. 1. Manual grid template used to quantify Goldmann visual fields.

Top: The grid template made up of 100 dots was used to score I4e isopter of the left eye Goldmann field (adapted from Esterman).³ Bottom: A small grid template also made up of 100 dot was used to score I2e isopter (adapted from Kwon et al).⁴

and during the study period. These included the patients' demographic information, as well as ocular, medical, and family history. All patients had complete ophthalmic evaluation, including manifest refraction, visual acuity, visual field testing (with a Goldmann perimetry), slit lamp examination of the anterior segment, IOP measurement with Goldmann applanation tonometer, and fundus examination including cup-to-disc ratio (C/D ratio) evaluation.

For numerical analysis, the visual acuity was converted to the logarithm of the minimal angle of resolution (logMAR) value according to the following equation: $\log\text{MAR} = -\log(\text{decimal visual acuity})$. For visual acuity of counting finger or worse, the following arbitrary conversion was used: counting finger greater than 1.2 meter = 2.0, counting finger 0.6 to 1.2 meter = 2.1, counting finger 0.3 meter or less = 2.2, hand motions = 2.3, light perception = 2.6, and no light perception = 2.9.⁵

The degree of cataract was graded into 7 stages from 0 (clear normal lens) to 6 (dense cataract). Nuclear sclerosis was graded into 4 stages from mild (+1) to very severe (+4). Cortical opacity and posterior subcapsular cataracts each merited an additional score of +1. In order to minimize the effect of cataract, we excluded the visual fields with visual acuity worse than 0.4 due to cataract. However, the visual fields with decreased visual acuity due to glaucoma were not excluded.

The differences between POAG and PACG in the categorical variables were compared using Chi-square test. Fisher's exact test was performed if the variables had less than 5 subjects. Mann-Whitney U test was used for continuous variables. To estimate the rate of visual field loss in each subject, linear regression analysis was performed on all eligible visual field scores according to time. To determine the correlation between the rate of visual field loss and each clinical variable, Mann-Whitney U test or one-way ANOVA was performed for categorical variables in each group. For continuous variables, linear regression analysis was performed using the rate of visual field loss as the dependent variable. The clinical factors used for the correlation analysis were as follows: age at initial visual field test, gender, left and right eye, visual acuity, concomitant systemic diseases (arterial hypertension or diabetes mellitus), use of systemic medication or not, the highest IOP in the past history, various clinical variables at the initial visual field test (visual acuity, refraction, IOP, number of anti-glaucoma medications, C/D ratio, field score), the highest IOP in the entire study period, averages of the highest and lowest IOP in each year, average of the range of IOP in each year, average IOP at every visit for the visual field test, number of glaucoma surgeries during follow-up, highest cataract score during follow-up, and

Table 1. Patients characteristics of primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) groups

Variables	POAG (n = 23)	PACG (n = 25)	p-value
Age (years, mean(S.D) range	55.3 ± 7.7 41 ~ 71	56.1 ± 8.3 43 ~ 74	0.664* -
Refraction (spherical equivalent, diopter)	-0.83 ± 1.31	-1.11 ± 1.50	0.680*
Gender, female	6 (26.1%)	14 (56.0%)	0.076†
Side, right eye	11 (47.8%)	12 (48.0%)	0.958†
Follow up (years)	11.7 ± 2.4	10.8 ± 3.9	0.439*
Concomitant systemic hypertension	3 (13.0%)	6 (24.0%)	0.466†
Concomitant diabetes mellitus	4 (17.4%)	2 (8.0%)	0.407†
Surgical History			
glaucoma laser surgery	3 (13.0%)	7 (28.0%)	0.375†
glaucoma filtering surgery	6 (25.0%)	3 (12.5%)	0.600†

*: Mann-Whitney U test, †: Pearson's chi-square test or Fisher's exact test (if number in a cell < 5).

final C/D ratio. Variables that showed a possible association with the rate ($p < 0.10$) were then included in the multiple linear regression model. Stepwise selection and forward selection were used to select the variables to be included in the final multiple linear regression model. SPSS (version 11.0) was used for statistical analysis, and p values less than 0.05 were considered significant.

RESULTS

Twenty-three eyes in the POAG group and 25 in the PACG group satisfied the inclusion and exclusion criteria. The average age at the initial visual field test was 55.3 ± 7.7 years in the POAG group and 56.1 ± 8.3 years in the PACG group, which was not significantly different ($p = 0.664$). Males were predominant in both groups, without significant difference ($p = 0.076$). The left and right eyes were evenly affected in both groups ($p = 0.958$). The refractive error was -0.83 ± 1.3 diopters in the POAG group and -1.11 ± 1.5 diopters in the PACG group ($p = 0.680$). The follow-up period was 11.7 ± 2.4 years in the POAG group and 10.8 ± 3.9 years in the PACG group ($p = 0.439$). The number of glaucoma surgeries undergone before the initial visual field test was 9 eyes in the POAG group: laser glaucoma surgery in 3 eyes and glaucoma incisional surgery in 6. For the PACG group, the number of glaucoma surgeries undergone before the initial visual field test was 10 eyes: laser glaucoma surgery in 7 eyes and glaucoma incisional surgery in 3.

There was no significant difference in the number of laser and incisional surgeries between the two groups ($p = 0.375$ and 0.600 , respectively). No significant difference was seen in the number of eyes with arterial hypertension and diabetes mellitus between the two groups (Table 1).

The average of IOP at every visit for the visual field test was 17.2 ± 2.8 mmHg and 19.5 ± 5.3 mmHg, in the POAG and PACG groups, respectively ($p = 0.219$). The average of the highest IOP in each year was significantly higher in the PACG group (22.0 ± 5.4 mmHg) than the POAG group (18.3 ± 2.2 mmHg) ($p = 0.006$). The average of the lowest IOP in each year during follow-up was 13.7 ± 2.5 mmHg for the POAG group and 14.5 ± 2.5 mmHg for the PACG group, and this showed no significant difference between the two groups ($p = 0.529$). The average of IOP range in each year was 4.5 ± 1.6 mmHg and 7.0 ± 3.9 mmHg for the POAG and PACG groups, respectively, and the PACG group showed a wider range ($p = 0.008$). The highest IOP in the entire study period was 26.7 ± 5.8 mmHg and 35.6 ± 15.8 mmHg in the POAG and PACG groups, respectively, with the higher PACG group value showing borderline statistical significance ($p = 0.067$). During the study period, laser procedure for glaucoma was performed in 3 eyes (13%) for the POAG group (laser peripheral iridoplasty) and in 17 eyes (68%) for the PACG group (laser peripheral iridotomy), which showed significantly greater frequency for the PACG group ($p = 0.000$). Fourteen glaucoma incisional surgeries were

Table 2. Change of intraocular pressure (IOP) and number of surgeries in primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) groups during the study period

Clinical characteristics	POAG (n = 23)	PACG (n = 25)	p-value
IOP (mean \pm S.D., mmHg)			
average IOP at every visit for visual field test	17.2 \pm 2.8	19.5 \pm 5.3	0.219*
average of the highest IOP in each year	18.3 \pm 2.2	22.0 \pm 5.4	0.006*
average of the lowest IOP in each year	13.7 \pm 2.4	14.5 \pm 2.5	0.529*
average of IOP range in each year	4.5 \pm 1.6	7.0 \pm 3.9	0.008*
highest IOP in entire study period	26.7 \pm 5.8	35.6 \pm 15.8	0.067*
Number of surgeries, eyes (% , number of procedures)			
glaucoma laser surgery	3 (13%, 3)	17 (68%, 18)	0.000†
glaucoma filtering surgery	12 (52%, 14)	10 (40%, 12)	0.309*

*: Mann-Whitney U test, †: Pearson's chi-square test or Fisher's exact test.

performed in 12 eyes (52.2%) for the POAG group and 12 glaucoma incisional surgeries were performed in 10 eyes (40.0%) for the PACG group. The rate of incisional surgical intervention showed no significant difference between the two groups ($p = 0.309$) (Table 2).

In the POAG group, the mean visual acuity was decreased from 0.98 (range; 0.7 to 1.5) at the initial visual field test to 0.63 (range; no light sense to 1.2) at the final visual field test ($p = 0.039$). The average IOP was decreased from 19.1 ± 4.3 mmHg to 15.4 ± 3.0 mmHg ($p = 0.006$), and the average C/D ratio was increased from 0.64 ± 0.23 to 0.84 ± 0.14 ($p = 0.000$). The number of anti-glaucoma medications was not changed significantly from 1.3 ± 1.0 to 1.0 ± 1.1 ($p = 0.362$). In the PACG group, the average visual acuity was decreased from 0.87 (range; 0.5 to 1.5) at the initial visual field test to 0.44 (range; no light sense to 1.2) at the final visual field test ($p = 0.012$). The average IOP was decreased from 25.2 ± 14.9 mmHg to 17.9 ± 5.2 mmHg ($p = 0.007$). The average C/D ratio was increased from 0.52 ± 0.25 to 0.77 ± 0.22 ($p = 0.001$). The number of anti-glaucoma medications was not changed from 1.3 ± 1.0 to 1.2 ± 0.7 ($p = 0.865$). However, these clinical factors showed no significant difference between the two groups at the initial and final visual field tests. None of the eyes in the POAG group but 3 eyes of the PACG group underwent cataract surgery before the initial visual field test. There was no significant difference in the frequency of cataract surgery between the two groups ($p = 0.235$). Six eyes in each group underwent cataract surgery during fol-

low-up (26.1% in the POAG group and 24.0% in the PACG group, $p = 0.565$). Cataract score at the initial visual field test was 0.22 ± 0.52 in the POAG group and 0.14 ± 0.35 in the PACG group. Maximal cataract score during follow-up was 1.00 ± 1.17 in the POAG group and 1.00 ± 1.44 in the PACG group. Both cataract scores showed no significant difference between the two groups ($p = 0.567$ in initial score, $p = 0.583$ in maximal score) (Table 3).

The number of visual fields that satisfied the inclusion criteria for analysis was 4.1 ± 1.6 in each patient in the POAG group and 5.5 ± 2.8 in the PACG group. A total of 231 Goldmann visual fields were analyzed for the rate of visual field progression. In the POAG group, the visual field score was 55.9 ± 28.0 at the initial visual field test and 45.6 ± 24.0 at the final visual field test. In the PACG group, the score was 66.8 ± 23.9 at the initial visual field test and it was decreased to 43.3 ± 26.9 at the final visual field test. By simple linear regression analysis, the calculated rate of visual field loss per year was -0.81 ± 1.00 (range: $-3.23 \sim 0.84$) in the POAG group and -2.00 ± 1.97 (range: $-5.58 \sim 1.78$) in the PACG group. The rate of visual field progression was significantly higher in the PACG group than the POAG group ($p = 0.018$, Table 4).

According to the analysis to find the clinical factors correlated with the progression of visual field loss, the rate of visual field loss was not correlated with gender or the affected side in the POAG and PACG groups. Nor was there any significant correlation with the presence of arterial hypertension or diabetes mellitus. In the POAG group, the first field

Table 3. Clinical characteristics of primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) groups on initial and final visits

Clinical characteristics	POAG (n = 23)	PACG (n = 25)	p-value*
†VA, logMAR (D.E.)			
Initial	0.008 ± 0.09 (0.98)	0.060 ± 0.14 (0.87)	0.333
final	0.201 ± 0.61 (0.63)	0.356 ± 0.72 (0.44)	0.444
p-value‡	0.039	0.012	
IOP (mmHg)			
Initial	19.1 ± 4.3	25.2 ± 14.9	0.292
final	15.4 ± 3.0	17.9 ± 5.2	0.161
p-value‡	0.006	0.007	
C/D ratio			
initial	0.64 ± 0.23	0.52 ± 0.25	0.102
final	0.84 ± 0.14	0.77 ± 0.22	0.333
p-value‡	0.000	0.001	
No. of glaucoma medications			
initial	1.34 ± 1.03	1.32 ± 0.80	0.782
final	1.02 ± 1.05	1.24 ± 0.72	0.271
p-value‡	0.362	0.865	
Cataract score§			
initial	0.22 ± 0.52	0.12 ± 0.33	0.567
maximal	1.00 ± 1.17	1.00 ± 1.44	0.583

*: Mann-Whitney U test, †: Visual acuity in logMAR (decimal equivalent), ‡: Wilcoxon signed ranks test, §: Cataract was scored from 0 (none) to 6 (very dense), according to the level of cataract.

Table 4. Change in visual field score of primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) during the study period

Variables	POAG (n = 23)	PACG (n = 25)	p-value*
No. of visual field tests	4.1 ± 1.6	5.5 ± 2.8	0.009
Initial Score	55.9 ± 28.0	66.8 ± 23.9	0.170
Final Score	45.6 ± 24.0	43.3 ± 26.9	0.584
Follow up (years)	11.7 ± 2.4	10.8 ± 3.9	0.439
Rate of visual field progression	-0.81 ± 1.00	-2.00 ± 1.97	0.018
Range of slope	-3.23 ~ 0.84	-5.58 ~ 1.78	-
Coefficient of determination (R ²)	0.86 ± 0.28	0.74 ± 0.31	-

*: Mann-Whitney U test.

score was the only variable that showed a significant correlation with the progression of visual field loss ($r = -0.510$, regression coefficient = -0.018 , $p = 0.013$). In the PACG group, the progression of visual field loss was significantly related with IOP factors; i.e., the highest IOP on the past history ($p = 0.038$), IOP at the initial visual field test ($p = 0.000$), average of IOP at every visit for the visual field test ($p = 0.000$), average of the highest IOP in each year ($p = 0.002$), and average of the lowest IOP in each

year ($p = 0.020$). A significant correlation was shown also with logMAR visual acuity at the initial visual field test ($p = 0.034$). All of these factors which significantly correlated with the rate showed negative correlation in both groups. Thus, faster progression of visual field loss was seen in those patients with larger scores of these factors (Table 5). The average of the IOP range in each year showed borderline significance with the rate of progression ($p = 0.051$) in the PACG group. For this group, the

Table 5. Clinical factors associated with the rate of VF (visual field) decline in primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) groups, by simple linear regression

Variables	POAG (n = 23)		PACG (n = 25)	
	p-value	Slope*	p-value	slope*
Highest IOP on history	0.435	-	0.038	-0.053
IOP at visit for first VF test	0.554	-	0.000	-0.092
Average of				
IOP at every visit for VF test	0.428	-	0.000	-0.281
the highest IOP in each year	0.564	-	0.002	-0.219
the lowest IOP in each year	0.917	-	0.020	-0.360
range of IOP in each year	0.699	-	0.051	-0.199
Visual acuity at visit for first VF test (logMAR)	0.461	-	0.034	-6.004
Visual field score on first VF test	0.013	-0.018	0.716	-

*: Regression coefficient (change in rate for each unit increment), IOP: Intraocular pressure.

multiple variables that showed a possible association ($p < 0.1$) were then included in the multiple linear regression model. Of these, only the average of the highest IOP in each year was selected and it showed a negative correlation with the progression of visual field loss ($r = -0.886$, regression coefficient = -0.276 , $p = 0.000$).

There was no correlation with the progression of visual field loss in both groups in the remaining factors; i.e., the age at the initial visual field test, number of glaucoma filtration surgeries during follow-up, cataract score, number of anti-glaucoma medications and the C/D ratio at the initial visual field test.

DISCUSSION

There have been a few reports about the rate of progression of visual field loss in POAG. Rasker et al⁶ reported a study using automatic perimetry (Peritest®, Rodenstock, Munich, Germany) with a mean follow-up of 8 years. In their study, the visual field declined at the rate of -1.3% per year in POAG. More recently, Kwon et al⁴ reported a rate of progression of -1.5% per year using Goldmann perimetry, with a mean follow-up of 14 years. The rates of progression from their study were slightly faster than those of the present study for the POAG group. Differences in the subject group may yield different result, as Kwon et al. stated the possibility that underlying diseases could have resulted in a worse glaucoma prognosis since their study contained many patients with vascular disease in the

fellow eye. Furthermore, the patients in their study were older than ours, and their patients were Caucasians.

In some studies, the rate of automated visual field decline in POAG has also been reported in decibel (dB) loss per unit time rather than in percentage loss. Smith et al⁷ reported the average rate of progression to be -0.11 dB per year during a follow-up of 7 years, and O'Brien et al⁸ reported -0.35 dB per year during 4-year follow-up. Rasker et al⁶ reported the method of converting the loss of visual field expressed in decibel into percentage (1% change equivalent to 0.23 dB). Based on this conversion factor, -0.81% (for the POAG patients in the present study), -1.3% (Rasker et al⁶), and -1.5% (Kwon et al⁴) per year would represent -0.19 dB, -0.30 dB, and -0.35 dB per year, respectively. Our result lies midway between the lowest rate (-0.11 dB per year from Smith et al.) and the highest rate (-0.35 dB per year from O'Brien et al. and Kwon et al.). However, direct comparisons may be difficult due to differences in various factors such as study design and subjected group.

As mentioned above, there are a few studies about rate of visual field loss in POAG^{4,6-14}; however the progression of visual field loss in PACG has not been so well studied. A search of the MEDLINE database did not reveal any study that looked for the rate of progression of visual field loss and associated clinical factors, using the same visual field test during a long-term period of over 10 years in PACG.

According to the results of the present study, the

progression of visual field loss was faster in the PACG group than the POAG group. In the PACG group, this progression of visual field loss showed a significant correlation with 5 factors associated with IOP. In addition, one remaining IOP factor (the average of the IOP range in each year) showed borderline significance. On the other hand, there was no correlation between the rate of progression and any IOP factor in POAG. This contrary relationship between the rate of visual field loss and IOP factors for the two study groups could be analyzed as follows. During the study period IOP was not controlled well in the PACG group compared to the POAG group. In the PACG group, the average IOP at every visit for the visual field test was 19.5 ± 5.3 mmHg, the average of the highest IOP in each year was 22.0 ± 5.4 mmHg, and the average of IOP range in each year was 7.0 ± 3.9 mmHg. On the other hand, IOP was relatively well controlled in the POAG group; IOP at every visit was 17.2 ± 2.8 mmHg, the highest IOP in each year was 18.3 ± 2.2 mmHg, and IOP range in each year was 4.5 ± 1.6 mmHg. The average of the highest IOP and the average of IOP range in each year showed a significant difference between the two groups. Thus, direct comparison between the two groups may not be appropriate since IOP is thought to be the most important factor in glaucoma progression and its control status was not the same for the two groups. However, considering that cases with poor IOP control are more frequent in the clinical field in PACG than in POAG, and given that we enrolled all the patients in our clinics who fulfilled the inclusion and exclusion criteria, this difference can be thought to have clinical importance in itself.

In this study, IOP was relatively well controlled in patients with POAG who underwent standard treatment. Nonetheless, the visual field loss was progressive and this progression did not show significant correlation with the IOP factors. A similar result was also identified in previous studies.^{8,11,15} The finding of a no significant correlation between the progression of visual field loss and IOP factors could be interpreted as follows. First, the vulnerability to increased IOP in each subject could have been too variable to reach statistical significance. Second, factors other than IOP may have played a role in the progression of visual field defect. Third, there might

have been cases who experienced increased IOP at some instance, but were not recorded. The hypotheses that patients with POAG could have a different vulnerability to IOP and that factors other than IOP factors could participate in progressive visual field loss for POAG have also been proposed in previous studies.^{16,17} On the other hand, the PACG group showed strong correlation with the IOP factors. This result suggests that the progression of visual field loss in PACG is more dependent on IOP, as compared with POAG; i.e., that the pathophysiology of both diseases is not the same. However, in order to confirm this hypothesis, further study under identical IOP control status is needed.

Aging is considered to be one of the causes of visual field loss progression that is irrelevant to IOP; however, the progression of visual field loss due to aging was reported as -0.06 dB per year in normal individuals,¹⁸ which was relatively small compared with the value found in the present study. Thus, aging probably does not significantly affect the results of this study. Also, the effects of cataract could be considered as another cause of visual field loss progression, irrelevant to IOP. However, we excluded those cases with a poor visual acuity due to cataract and the change of cataract score during this study was small. Although we could not eliminate the effect of cataract on the rate of visual field progression completely, we think that the effect of cataract in this study may not be very significant.

The rate of visual field loss was slower as the score of the initial visual field test decreased in the POAG patients, and this was similar to the finding by O'Brien et al.⁸ In general, the central field was known to be more resistant to damage than the peripheral field. Only the central field remained in most of those eyes with a small field score at the initial visual field test. We think that this fact could explain the inverse correlation between the rate of visual field loss and the initial visual field score in the POAG group. In patients with PACG, however, no significant correlation was seen with the score of the initial visual field test. For some patients, especially those with poorly controlled IOP in the PACG group, even the central field was rapidly damaged. We consider that this caused the lack of correlation between the field score and the rate of field loss in the PACG group.

In the PACG group, a faster progression of visual field loss was seen with poorer visual acuity at the initial visual field test. Most patients in this study had good central vision, even in those with terminal stage of glaucoma. IOP averaged 36.4 ± 19.3 mmHg in 9 eyes with poor initial visual acuity of less than 0.8 at the initial visual field test, which was relatively high compared with 19.0 ± 5.5 mmHg in patients with good visual acuity. Most of these patients with poor visual acuity showed normal visual field before progression at the initial visual field test, and only one case had an advanced visual field defect. With correlation analysis, visual acuity at the initial visual field test was correlated inversely with initial IOP ($p = 0.002$, $r = -0.578$), but not with initial visual field score ($p = 0.534$, $r = 0.131$). Thus, the visual acuity at the initial visual field test could have reflected the IOP status rather than the visual field status, which is in line with the finding mentioned previously where IOP at the initial visual field test and the rate of visual field loss were correlated in patients with PACG.

We excluded 3 patients from the study as they did not receive appropriate treatment during the study period. One was a POAG patient who was lost from follow-up for 3 years, and who returned with an increased IOP of 38 mmHg. This patient showed a progression of visual field loss of -5.45% per year. The other 2 patients were PACG cases. One was lost from follow-up for 3 years, and returned with an increased IOP (32 mmHg) and a rate of visual field loss of -2.84% per year. The other patient was also lost from follow-up for 3 years and returned with a high IOP (44 mmHg). Surgery was recommended for IOP control, but this patient delayed surgery for 4 years. The final rate of visual field loss was -7.31% per year in this patient. As seen in these cases, eyes with glaucoma that were not on proper IOP control may show a faster progression of visual field loss than subjects who underwent the standard treatment.

In this study, we excluded all subjects with other ocular diseases, except for glaucoma and mild cataract, applied a strict follow-up period criteria, applied the same test methods, and included only those patients who were under standard treatment for the study period. Consequently many subjects were excluded, and this study therefore has a limita-

tion due to the small number of subjects. Nonetheless, as POAG and PACG were compared under the same conditions at referral hospitals for an average of more than 10 years, the data obtained in this study could be used as pilot data for researching the pathophysiology of PACG.

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