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The Frequency of Optical Coherence Tomography Testing in Glaucoma at a Single Academic Medical Center

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Abstract

Purpose—To determine the frequency of optical coherence tomography (OCT) examinations compared to clinical examinations and visual field (VF) tests in patients with five types of glaucoma.

Patients and Methods—A retrospective, longitudinal cohort study was conducted of 5,154 patients treated between 2003–2010 at a single academic medical center. Patients were classified using billing records as having primary open-angle glaucoma (POAG), low tension open-angle glaucoma (NTG), pigmentary open-angle glaucoma (PG), chronic angle-closure glaucoma (CACG), or pseudoexfoliation glaucoma (PXG). Analysis of variance, χ^2 test, and exact χ^2 test were performed to identify associations between glaucoma type and test frequency.

Results—PG and NTG patients had a higher rate of undergoing at least two VFs (94.4%, 94.9%), and CACG patients had a lower rate of undergoing at least two OCTs (25.3%) than all other glaucoma types. NTG patients also had the highest rate of undergoing at least two OCTs and at least two VFs (36.6%). Overall, the rate of clinical examinations (2.68 exams/year) exceeded the rates of OCTs (1.39 exams/year), which exceeded the rate of VF tests (1.24 tests/year). There were no differences in OCT frequency between glaucoma types (0.91–1.63 OCT/year). Within each glaucoma diagnosis, patients had clinical examinations more frequently than OCTs and clinical examinations more frequently than VFs. POAG and PXG patients also had OCTs more frequently than VFs. More patients had at least two VF tests than at least two OCTs (4,481 vs. 1,679).

Conclusion—The relative use of clinical examinations, VF testing, and OCT imaging varies amongst glaucoma diagnoses.

Keywords

Glaucoma evaluation; ancillary testing; optical coherence tomography; visual field testing

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Conflicts of Interest:

JLG has no relevant conflicts to report.

Introduction

Glaucoma is a group of diseases characterized by progressive optic neuropathy and characteristic visual field losses that can lead to blindness. Ophthalmologists have traditionally assessed glaucoma patients with optic nerve head slit lamp examinations, optic nerve head photographs, and visual field (VF) testing. Optical coherence tomography (OCT) is a newer imaging technology that uses reflected light from the retina to measure the thickness of each retinal layer. The use of OCT for evaluating patients with glaucoma has grown in popularity since it was initially reported in 1991¹ and is now a frequently used tool for diagnosing and charting the progression of glaucomatous retinal nerve fiber layer degeneration.²

Current guidelines from the American Academy of Ophthalmology (AAO) and European Glaucoma Society offer recommendations on how frequently patients should be evaluated with clinical examinations and VF tests.^{3,4} On the other hand, ophthalmologists lack guidelines on how frequently patients should undergo OCT examinations. Guidelines recommend optic nerve head assessments, but do not endorse a specific technique such as slit lamp examinations with drawings, stereophotographs, or computer-based imaging technology (e.g., OCT, confocal scanning lasers, or scanning laser polarimetry).^{3,4} This study compares the frequency of OCTs to the frequencies of clinical examinations and VF tests in patients with five common types of glaucoma at one academic medical center.

Materials and Methods

A longitudinal, retrospective cohort study was conducted at an academic medical center using international classification of disease (ICD-9) and current procedure terminology (CPT) billing records from June 1, 2003– November 30, 2010. All patients were aged 40 or above at the time of their last clinical examination. Age at last clinical examination was utilized because patient age was not accessible for patients who first presented outside the study period (prior to June 1, 2003). All patients were classified using ICD-9 billing records as having primary open-angle glaucoma (POAG [365.11]), low tension open-angle glaucoma (NTG [365.12]), pigmentary open-angle glaucoma (PG [365.13]), chronic angle-closure glaucoma (CACG [365.23]), or pseudoexfoliation glaucoma (PXG [365.52]). This study did not include patients who were glaucoma suspects (365.0–365.04). No charts were reviewed. The University of Miami Institutional Review Board Human Subjects Research Office approved this study. This research was conducted in accordance with the tenets of the Declaration of Helsinki.

Patients were included in the study if they had at least three clinical examinations with the same glaucoma diagnosis, based on ICD-9 codes, and received follow-up care in ophthalmology clinics over at least two years. The number of clinical examinations was determined based on the number of ophthalmology clinic visits. Patient visits associated with a surgery, ophthalmology emergency room, or testing-only encounter code were not included in the clinical examination calculation. Each patient was categorized as having one type of glaucoma to ensure that each glaucoma subset was composed of unique patients. Patients were excluded if they met the criteria for more than one glaucoma diagnosis (at

least three clinical examinations for over two years for each glaucoma diagnosis). Patients were included in the VF or OCT frequency analysis if they had at least two of the respective test. OCT examinations included CPT 92135. VF tests included CPT 92083 “VF Test Extended”. CPT 92081 “VF Test Limited” and CPT 92082 “VF Test Intermediate” were not included because a preliminary analysis demonstrated that these two codes made up less than 0.2% of all VF tests in the study population.

Clinical examination frequencies were calculated for each patient by dividing the total number of clinical examinations by the time period between the first and last clinical examination. VF and OCT frequencies were calculated by dividing the number of VFs or OCTs, respectively, by the time period between the first and last clinical examination, thereby setting the denominator as the time frame during which the patient was treated. The number of OCTs was determined by date for each patient so that multiple OCTs on the same date were counted only once. The same procedure was applied for VFs and clinical examinations.

Testing frequency trends were analyzed for years 2005–2009 because there were approximately 75% fewer OCTs in 2004 than 2005 and there was less than 12 months of data for 2003 and 2010. In calculating the average number of OCTs, VFs, and clinical examinations per patient per year, we used the number of patients with a clinical exam in that year as the denominator. The total number of OCTs per year was also expressed as a ratio of total OCTs to total clinical examinations to determine if the use of OCTs increased during 2005–2009. The same procedure was utilized for VFs.

Statistical analysis was performed using SPSS Version 19 (SPSS Inc, Chicago, Illinois) and JMP Version 10 (SAS Institute Inc, Cary, North Carolina). Categorical variables were analyzed with the χ^2 test or exact χ^2 test. Continuous variables were analyzed with the Independent T-Test and Single Factor Analysis of Variance (ANOVA). Bonferroni Post-Hoc T-Test was utilized when ANOVA results had a $P < 0.05$.

Results

5,154 patients met the inclusion criteria of three or more clinical examinations with the same glaucoma diagnosis and more than two years of follow-up. 1,679 patients had at least two OCT examinations, and 4,481 patients had at least two VF tests. There were 57,501 clinical examinations, 24,799 VFs, and 10,890 OCTs during the 7.5 year study period. 2,142 (41.6%) of the patients in this study were seen for at least five years.

Patient demographic information is listed in Table 1. Overall, the mean age was 73.4 ± 11.8 years old. Patients with PXG were on average older than patients with every other type of glaucoma, and patients with PG were younger than patients with every other type of glaucoma (both $P < 0.01$, ANOVA and Bonferroni Post-Hoc T-Test). There was no difference in mean age amongst POAG, NTG, and CACG patients ($P > .05$, Bonferroni Post-Hoc T-Test). CACG patients were more likely to be female and PG patients were more likely to be male than observed in patients with other glaucoma types ($P < 0.01$, χ^2 Test).

We next explored whether the proportion of patients who had zero, one, or at least two OCTs and VFs differed among glaucoma types. The type and number of tests for patients is summarized in Table 2. Overall, 86.9% of patients had at least two VFs, 7.3% had one VF and 5.7% had no VF (Figure 1). PG and NTG patients had a higher rate of undergoing at least two VFs (94.4%, 94.9%) than all other glaucoma types (76.9%–87.4%) ($P<0.001$, Exact χ^2 Test). CACG and PXG patients had the lowest rates of completing at least two VFs (76.9–80.4%) ($P<0.001$, χ^2 Test). Overall, 32.6% of patients had at least two OCTs, 24.6% had one OCT, and 42.9% had no OCT (Figure 1). CACG patients had a lower rate of undergoing at least two OCTs (25.3%) than all other glaucoma types (29.1%–37.8%) ($P=0.023$, χ^2 Test). Together, 30.0% of patients had at least two OCTs and at least two VFs (range 23.5%–36.6%). NTG patients had a higher rate of undergoing at least two OCTs and at least two VFs (36.6%) than all other glaucoma types (23.5%–31.5%) ($P<0.01$, χ^2 Test). We next examined length of follow-up by glaucoma type. POAG patients had a longer mean follow-up (4.62 years, SD=0.026) than NTG patients (4.27 years, SD= 0.091) ($P<0.0005$). There were no other differences in mean follow-up time by glaucoma diagnosis. The mean follow-up time by diagnosis did not correlate with the proportion of patients who had at least two VFs, OCTs, or both.

Do clinical examination, VF, and OCT frequencies differ by glaucoma diagnosis? Taking all diagnoses together, the mean clinical examination frequency of 2.68/year ($N=5,154$, SD=1.36) exceeded the mean OCT frequency of 1.39/year ($N=1,679$, SD=1.87), which exceeded the VF frequency of 1.24/year ($N=4,481$, SD=0.61) ($P<0.001$, ANOVA and Bonferroni Post-Hoc T-Test) (Figure 2). Among different diagnoses, the clinical examination frequency for POAG (2.71/year) exceeded PG (2.13/year) ($P=0.02$, ANOVA and Bonferroni Post-Hoc T-Test) (Table 3 and Figure 3). No other differences in clinical examination frequency were detected between glaucoma types. No difference in OCT frequency was detected between glaucoma types (range 0.91–1.63 OCT/year, $P=0.55$, ANOVA). VF frequencies, however, differed among glaucoma diagnoses ($P<0.01$, ANOVA and Bonferroni Post-Hoc T-Test) (Table 3 and Figure 4). Within each glaucoma diagnosis, patients had clinical examinations more frequently than OCTs and clinical examinations more frequently than VFs ($P<0.001$, ANOVA and Bonferroni Post-Hoc T-Test). In addition, POAG and PXG patients had OCTs more frequently than VFs ($P<0.01$, ANOVA and Bonferroni Post-Hoc T-Test) (Figure 2).

We next asked whether patients who had more OCTs or more VFs had more frequent clinical examinations. Patients who had at least two OCTs had more frequent clinical examinations (2.85/year) than patients who had one OCT (2.72/year), and patients with one OCT had more frequent clinical examinations than patients with zero OCT (2.53/year) ($P<0.05$, ANOVA and Bonferroni Post-Hoc T-Test) (Table 4), possibly reflecting disease severity (not studied here; see discussion). Patients who had at least two VFs had more frequent clinical examinations (2.76/year) than patients who had one VF (2.23/year) and patients who had zero VF (2.10/year) ($P<0.001$, ANOVA and Bonferroni Post-Hoc T-Test) (Table 5). There was no difference in clinical examination frequency between patients who had one VF and zero VF ($P=0.67$, ANOVA and Bonferroni Post-Hoc T-Test). The small differences in years of patient follow-up by total OCT or VF number did not correlate with clinical examination frequency in this regard (Table 4 and Table 5).

Is there a change in how often patients underwent VF and OCT testing during the study period? Figure 5 demonstrates the number of clinical examinations, OCTs, and VFs per year during the five-year period with the most clinical examinations. The total number of OCTs increased from 1122 in 2005 to 1844 in 2009. The total number of VFs decreased from 3460 in 2005 to 3307 in 2009. We then examined the average number of clinical examinations, OCTs, and VFs per patient for each year during 2005–2009 (Figure 6). The average number of OCTs per patient was lower in 2005 (0.37) than all other years (0.47–0.57, ANOVA, $P < 0.005$), and lower in 2006 (0.47) than 2007 and 2008 (0.56 and 0.57, respectively, $P < 0.005$). The average number of VFs per patient was higher in 2005 (1.15) than all other years (0.95–1.02, ANOVA $P < 0.0001$), and higher in 2006 (1.02) than 2008 and 2009 (0.98 and 0.95, respectively, $P = 0.002$). The average number of clinical examinations per patient was higher in 2005 (2.60) than 2006 and 2009 (2.49 and 2.45, respectively, $P < 0.0001$), and higher in 2008 (2.58) than 2009 (2.45, $P < 0.001$). There were no other differences in the number of OCT, VFs or clinical examinations ($P > 0.005$ including Bonferroni correction).

We then compared the number of patients with at least one clinical examination and without an OCT in a given year to the number of patients with at least one clinical examination and also one OCT. The proportion of patients with both an OCT and clinical exam was lower in 2005 than 2006–2009 (22.3% vs. 28.3–30.3%, $P < 0.0001$, χ^2 Test). There were no differences between 2006–2009 (28.3–30.3%, $P > 0.05$, χ^2 Test). The proportion of patients in a specific year with at least one VF and at least one clinical examination versus just a clinical examination was higher in 2005 than 2006–2009 (80.8% vs. 72.6–74.8%, $P < 0.0001$, χ^2 Test). Similarly the proportion was higher in 2006 than 2007 (74.8% vs. 72.6%, $P = 0.035$, χ^2 Test). There were no other differences between years 2006–2009 ($P > 0.05$, χ^2 Test).

Discussion

Our goal was to study the long-term evaluation of different types of glaucoma patients at a tertiary care referral center. Patients with various types of glaucoma have different rates of clinical examinations (mean 2.68/year), OCTs (mean 1.39/year), and VFs (mean 1.24/year). In addition, the proportion of patients who underwent at least two OCTs, VFs, or both varied between glaucoma types with NTG and PG patients having the highest rates of undergoing at least two VFs, and CACG patients having the lowest rates of undergoing at least two OCTs. Test frequencies were calculated for glaucoma patients who had at least two clinical examinations, VFs, or OCTs. We postulate that having two of a given test (e.g., a baseline and a follow-up) may demonstrate that the ordering physician is using the test to evaluate for possible disease progression, although other possibilities include a transition between time-domain OCT and spectral-domain OCT “baseline” exams. Although the mean rates of OCTs exceeded the mean rates of VFs, more patients had at least two VFs (4,481; 86.9%) than at least two OCTs (1,679, 32.6%). Overall, there were more VFs (24,799) than OCTs (10,890). This may reflect a preference for monitoring with VF examinations, although patients with more advanced glaucoma or co-morbid retinal disease may undergo OCTs more frequently than VFs. In addition, the results that patients with at least two OCTs had more frequent clinical exams than patients who had zero or one OCTs may signify that OCT frequency may be a marker for glaucoma disease severity.

We analyzed the use of OCTs and VFs over time by comparing the number of patients with an OCT and a clinical examination in the same year and by comparing the number of patients with a VF and a clinical examination in the same year because the number of patients varied each year. We chose 2005–2009 because these years had the most clinical examinations. 2005 had the highest proportion of patients with an examination and VF and the lowest proportion of patients with an OCT and examination. The use of VFs and OCTs remained fairly constant between 2006–2009.

The increasing utilization of OCT is reflected in the glaucoma literature. Patients under the exclusive care of an ophthalmologist for open-angle glaucoma in 2008 had similar odds of undergoing VF testing as computer-based imaging (confocal scanning laser ophthalmoscopy, scanning laser polarimetry or optical coherence tomography).⁵ For open-angle glaucoma patients from 2001 to 2009, there was a 147% increase in the odds of undergoing computer-based imaging and a 44% decrease in the odds of undergoing VF testing.⁵ The use of OCTs more frequently than VFs may reflect how OCT is a rapid, non-invasive test that produces quantitative, objective results. In addition, patients prefer computer-based imaging such as confocal scanning laser ophthalmoscopy to more involved technologies such as VF tests and fundus photography.⁶

The AAO Preferred Practice Pattern for Primary Open-Angle Glaucoma (2010) suggests that stable patients should have follow-up clinical examinations every 6–12 months and that unstable patients (intraocular pressure above goal and/or progression of disease) have follow-up clinical examinations every 1–2 or 3–6 months.³ The mean clinical examination frequency of 2.68/year in this study is more than that suggested by some previous data showing that 81.9% of new glaucoma patients follow-up at least every 18 months⁸, but less than the report of 4.3 ± 1.9 visits/year in a population of 281 open-angle glaucoma patients who recently started their first glaucoma medication.⁷ The increased frequency in this latter study may reflect the importance of frequent follow-up examinations when patients start a new medication. These frequencies may be modulated by disease state; in another study, 75.7% of mild and 82.9% of moderate to severe glaucoma patients had follow-up visits within 6 months in a study of 395 long-term open-angle glaucoma patients.⁹ Patients in our study had at least two years of follow-up so the clinical examination frequency may be relatively low if the majority of patients have stable disease. In addition, the two-year requirement was designed to minimize the inclusion of patients who were evaluated at this academic medical center for a second opinion without long-term follow-up because they may have outside VF and OCT results that are not included in our billing database.

The AAO Preferred Practice Pattern for Primary Open-Angle Glaucoma (2010) recommends optic nerve and visual field evaluations at the same frequency as follow-up clinic evaluations: every 6–12 months for stable patients and every 1–2 or 3–6 months for unstable patients.³ The mean VF frequency of 1.24/year observed here is higher than previous reports in which 38.1% of mild open-angle glaucoma patients and 56.6% of moderate to severe open-angle glaucoma patients had VF tests within 12-month intervals.⁹ Other studies reported that approximately 50% of patients underwent annual VF testing.⁷ The higher VF rate in our study may be due to referral bias if more patients have advanced or rapidly

progressive disease. Our patient population may also be more recently diagnosed than the patients in the Fremont *et al* study who had glaucoma for an average duration of 8 years.⁹

The frequent patient evaluations in this study have significant cost implications. Open-angle glaucoma affects approximately 2% of Americans age 40 and above.¹⁰ Patient evaluations with VFs, clinical examinations, and OCTs have significant costs to the U.S. medical system¹¹ with the annual direct cost of glaucoma care in 2004 estimated at \$2.9 billion.¹² Increased rates of patient evaluations in this study may reflect more aggressive glaucoma care and an increasing cost of glaucoma care. The cost and value of OCT in managing glaucoma is important given the discussion on whether nerve fiber layer changes on OCT may be used as a structural outcome measure in Food and Drug Administration-regulated glaucoma clinical trials.¹³

A strength of this study is the large number of patient records for both POAG and less common glaucoma diagnoses. The use of data from an academic medical center may reflect the patient population at a tertiary care center with an increased proportion of patients with PG, CACG, and PXG. Results from this study represent glaucoma management at this single, academic institution and the results may not be generalizable. Future studies could extend across institutions and practices, or utilize national healthcare databases to examine glaucoma management strategies across the country. The data reflects glaucoma management by physicians in all levels of training from residents to comprehensive ophthalmologists and glaucomatologists. The study is based on eight consecutive years of information and, therefore, examines long-term glaucoma management and changes in glaucoma management during the study period.

Limitations of the current study include the approach of retrospective data collection based on billing records without direct review of each patient's chart. Chart reviews can provide detailed information on how each patient is managed and can validate the accuracy of billing record diagnoses. A complete chart review of each of the 5,154 patient records was not undertaken due to resource limitations. This study excluded patients who were glaucoma suspects in order to evaluate the management of only patients who were classified as having a type of glaucoma. In a previous national, random chart review, only 38% of 268 patients with an open-angle glaucoma ICD-9 code met glaucoma criteria based on cup-to-disc grading and VF test results.⁷ The other 62% met criteria for glaucoma suspect.⁷ There was no analysis of charts to ensure the accuracy of specific glaucoma diagnoses (e.g., POAG versus NTG versus PG versus CACG versus PXG), and it is possible that physicians coded some patients with NTG, PG, or PXG simply as POAG. The inclusion criteria in the current study was designed to reduce the effects of coding mistakes by requiring patients to have the same ICD-9 code associated with at least three clinical examinations over at least two years.

Another limitation of ICD-9 coding is that it is impossible to determine the indication for each test. We calculated frequencies based on all VF tests and OCTs but were unable to determine which tests were for glaucoma. ICD-9 codes used during the study period do not differentiate optic nerve head OCTs from macular OCTs, and it was not possible to review each chart to determine the type of each OCT. In a related study of POAG patients with at least 8 VFs and 2 OCTs drawn from the same billing records, 76% of OCTs (93 of 123

OCTs) were optic nerve head OCTs and 24% were macular OCTs among 27 POAG patients with at least two OCTs and at least 8 VFs (unpublished data). The use of macular OCTs among patients with glaucoma likely represents concomitant retina disease, which is an area of limited research. Nevertheless, the frequency of ancillary testing for glaucoma management in this study may be inflated, but we believe this inflation is modest. Billing records can be incomplete so patient may have had more tests than are reflected in our dataset. 296 patients had zero VFs and an average clinic follow-up time of 4.2 years. The lack of VFs for these 296 patients may reflect inaccurate VF billing records instead of a lack of VFs, or severe enough disease that VF testing was of minimal clinical utility. In addition, 30% of patients had at least two OCTs and at least two VFs versus 32.6% of patients that had at least two OCTs. The 2.6% of patients who had at least two OCTs but did not have at least two VFs may reflect incomplete records, may represent patients who have difficulty taking VFs, or may represent patients who had OCTs for reasons other than glaucoma.

As glaucoma ICD-9 codes do not indicate disease severity, so we were unable to assess correlations between disease severity and patient management. It was, therefore, not possible to compare AAO Preferred Practice Guidelines to the clinical examination, OCT, and VF frequencies calculated in this study. Changes to the ICD-9 will include coding for disease severity and future studies may not have this limitation.

Future studies are needed to validate glaucoma management strategies and to assess national trends. Evaluation of the clinical impact of variable testing rates should also be undertaken, particularly as OCT continues to become a commonly utilized tool in the evaluation of glaucoma patients.

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Figure 1.
The number of visual field tests and optical coherence tomography exams for all study patients, regardless of glaucoma type.

Figure 2.

Clinical examination, OCT, and VF frequency by glaucoma type.

Clinical exam frequency exceeded VF and OCT frequencies within each glaucoma type ($P < 0.001$).

* For All Patients, the frequency of clinical examinations exceeded OCTs, which exceeded VFs ($P < 0.001$).

** OCT frequency exceeded VF frequency only for POAG and PXG ($P < 0.01$).

Figure 3.

Clinical examination frequency by glaucoma type

* The clinical examination frequency for POAG exceeded PG ($P < 0.05$). There were no other differences ($P > 0.05$).

Figure 4.

Visual field frequency by glaucoma type

* The VF frequency for NTG exceeded POAG, CACG, and PXG ($P < 0.001$).

** The VF frequency for POAG exceeded CACG and PXG ($P < 0.01$).

Figure 5.
Clinical exams, VFs, and OCTs per year: 2005–2009

Figure 6.
The average number of clinical exams, VFs, and OCTs per patient per year: 2005–2009

Table 1

Patient age and sex by glaucoma diagnosis

Age- no. (%) ^A	POAG (N=4171)	NTG (N=336)	PG (N=54)	CACG (N=277)	PXG (N=316)
40–49	153 (3.7%)	8 (2.4%)	2 (3.7%)	13 (4.7%)	0 (0%)
50–59	447 (10.7%)	45 (13.4%)	19 (35.2%)	31 (11.2%)	4 (1.3%)
60–69	966 (23.2%)	83 (24.7%)	16 (29.6%)	79 (28.5%)	30 (9.5%)
70–79	1258 (30.2%)	92 (27.4%)	10 (18.5%)	81 (29.2%)	114 (36.1%)
80–89	1068 (25.6%)	93 (27.7%)	6 (11.1%)	62 (22.4%)	127 (40.2%)
90	279 (6.7%)	15 (4.5%)	1 (1.9%)	11 (4.0%)	41 (13.0%)
Mean ± SD	73.2±11.9	72.8±11.5	65.0±11.7 ^B	71.3±11.6	80.5±8.4 ^B
Sex- no. (%)					
Female ^C	2286 (54.8%)	219 (65.2%)	17 (31.5%)	199 (71.8%)	185 (58.5%)
Male	1885 (45.2%)	117 (34.8%)	37 (68.5%)	78 (28.2%)	131 (41.5%)

Abbreviations: POAG, primary open-angle glaucoma; NTG, low tension open-angle glaucoma; PG, pigmentary open-angle glaucoma; CACG, chronic angle-closure glaucoma; PXG, pseudoexfoliation glaucoma; no., number; SD, standard deviation.

^A Age as of last clinical examination.

^B PXG mean age was older and PG mean age was younger than all other glaucoma types ($P<0.01$, ANOVA and Bonferroni Post-Hoc T-Tests).

^C CACG percent female exceeded all other glaucoma types ($P<0.01$, χ^2 Test). PG percent female was less than all other glaucoma types ($P<0.01$). There was no difference between POAG and PXG ($P=0.20$).

Table 2

Breakdown of patients by number of OCT examinations and VF tests

	POAG (N=4171)	NTG (N=336)	PG (N=54)	CACG (N=277)	PXG (N=316)	All Glaucoma Types (N=5154)
Mean Years Follow-Up (SD) ^A	4.62 (1.69)	4.27 (1.54)	4.93 (1.71)	4.40 (1.63)	4.43 (1.69)	4.58 (1.68)
No OCT (%) ^B	1770 (42.4%)	124 (36.9%)	26 (48.1%)	146 (52.7%)	143 (45.3%)	2209 (42.9%)
1 OCT (%)	1028 (24.6%)	85 (25.3%)	11 (20.4%)	61 (22.0%)	81 (25.6%)	1266 (24.6%)
2 OCT (%) ^C	1373 (32.9%)	127 (37.8%)	17 (31.5%)	70 (25.3%)	92 (29.1%)	1679 (32.6%)
No VF (%) ^D	219 (5.3%)	7 (2.1%)	1 (1.9%)	34 (12.3%)	35 (11.1%)	296 (5.7%)
1 VF (%)	308 (7.4%)	10 (3.0%)	2 (3.7%)	30 (10.8%)	27 (8.5%)	377 (7.3%)
2 VF (%) ^E	3644 (87.4%)	319 (94.9%)	51 (94.4%)	213 (76.9%)	254 (80.4%)	4481 (86.9%)
2 OCT and 2 VF (%) ^F	1260 (30.2%)	123 (36.6%)	17 (31.5%)	65 (23.5%)	83 (26.3%)	1548 (30.0%)

Abbreviations: OCT, optical coherence tomography; VF, visual field; POAG, primary open-angle glaucoma; NTG, low tension open-angle glaucoma; PG, pigmentary open-angle glaucoma; CACG, chronic angle-closure glaucoma; PXG, pseudoexfoliation glaucoma.

^A POAG patients had a longer mean follow-up than NTG patients (ANOVA and Bonferroni Post-Hoc T-Tests, $P<0.0005$). There were no other differences in follow-up by diagnosis ($P>0.05$).

^B CACG patients had a higher rate of undergoing zero OCT than all other glaucoma types ($P=0.002$, χ^2 Test). There were no differences between POAG, NTG, PG, and PXG patients ($P>0.05$).

^C CACG patients had a lower rate of undergoing 2 OCTs than all other glaucoma types ($P=0.023$, χ^2 Test). There were no differences between POAG, NTG, PG, and PXG patients ($P>0.05$).

^D PXG and CACG patients had higher rates of undergoing zero VF than all other glaucoma types ($P<0.01$, χ^2 and Exact χ^2 Test). There was no differences between PXG and CACG, PG and NTG, as well as PG and POAG ($P>0.05$).

^E NTG and PG patients had higher rates of undergoing 2 VFs than all other glaucoma types ($P<0.01$, Exact χ^2 Test). POAG patients had higher rates than CACG and PXG patients ($P<0.001$, χ^2 Test). There were no differences between NTG and PG, as well as CACG and PXG ($P>0.05$).

^F NTG patients had a higher rate of undergoing 2 OCTs and 2 VFs than all other glaucoma types ($P<0.01$, χ^2 Test). There was no differences between POAG, PG, CACG, and PXG ($P>0.05$).

OCT, VF, and clinical examination frequency

Table 3

	POAG	NTG	PG	CACG	PXG	P Value
Clinical Exam Frequency ^A						
Mean	2.71	2.54	2.13	2.61	2.64	<0.01
N	4171	336	54	277	316	
SD	1.37	1.02	0.94	1.44	1.5	
OCT Frequency ^B						
Mean	1.38	1.3	0.91	1.33	1.63	0.55
N	1373	127	17	70	92	
SD	1.83	1.94	0.56	1.97	2.44	
VF Frequency ^C						
Mean	1.24	1.43	1.18	1.07	1.08	<0.001
N	3644	319	51	213	254	
SD	0.6	0.71	0.51	0.49	0.53	

Abbreviations: OCT, optical coherence tomography; VF, visual field; SD, standard deviation; POAG, primary open-angle glaucoma; NTG, low tension open-angle glaucoma; PG, pigmentary open-angle glaucoma; CACG, chronic angle-closure glaucoma; PXG, pseudoexfoliation glaucoma.

^AClinical examination frequency for POAG exceeded PG (P=0.02, ANOVA and Bonferroni Post-Hoc T-Tests). There were no other differences between glaucoma types (P>0.05).

^BThere were no differences between glaucoma types (P=0.55, ANOVA).

^CVF frequency for NTG exceeded POAG, CACG, and PXG (P<0.001, ANOVA and Bonferroni Post-Hoc T-Tests). POAG exceeded CACG and PXG (P<0.01). There were no other differences (P>0.05).

Table 4

Clinical examination frequency and follow-up by OCT number

	0 OCT (N=2209)	1 OCT (N=1266)	2 OCTs (N=1679)
Clinical Examination Frequency^A			
Exams/Year (SD)	2.53 (1.29)	2.72 (1.32)	2.85 (1.44)
Years of Patient Follow-Up^B			
Years (SD)	4.60 (1.68)	4.46 (1.67)	4.64 (1.68)

Abbreviations: OCT, optical coherence tomography; SD, standard deviation.

^A Patients with 2 OCTs had more frequent clinical examinations than patients with 1 OCT and patients with 0 OCT ($P<0.05$, ANOVA and Bonferroni Post-Hoc T-Test). Patients with 1 OCT had more frequent clinical examinations than patients with 0 OCT ($P<0.05$).

^B Patients with 1 OCT had shorter follow-up than patients with 0 OCT and patients with 2 OCTs ($P<0.05$, ANOVA and Bonferroni Post-Hoc T-Test). There were no other differences ($P>0.05$).

Table 5

Clinical examination frequency and follow-up time by VF number

	0 VF (N=296)	1 VF (N=377)	2 VFs (N=4481)
Clinical Examination Frequency^A			
Exams/Year (SD)	2.10 (1.32)	2.23 (1.21)	2.76 (1.35)
Years of Patient Follow-Up^B			
Years (SD)	4.20 (1.50)	3.85 (1.52)	4.66 (1.69)

Abbreviations: VF, visual field; SD, standard deviation.

ANOVA and Bonferroni Post-Hoc T-Test were performed to compare means.

^A Patients with 2 VFs had more frequent clinical examinations than patients with 1 VF and patients with 0 VF ($P<0.001$, ANOVA and Bonferroni Post-Hoc T-Test). There were no other differences ($P>0.05$).

^B Patients with 2 VFs had longer follow-up than patients with 0 VF ($P<0.01$, ANOVA and Bonferroni Post-Hoc T-Test). Patients with 0 VF had longer follow-up than patients with 1 VF ($P<0.05$).