HHS Public Access

Author manuscript

Ophthalmol Glaucoma. Author manuscript; available in PMC 2023 November 01.

Published in final edited form as:

Ophthalmol Glaucoma. 2022 ; 5(6): 587–593. doi:10.1016/j.ogla.2022.05.002.

The frequency of visual field testing in a US nationwide cohort of individuals with open angle glaucoma

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Abstract

***Purpose*:** Visual field testing that isn't frequent enough results in delayed identification of open angle glaucoma (OAG) progression. Guidelines recommend at least annual testing. It is not known how frequently patients with OAG across the US receive visual field testing and how patient characteristics and circumstances influence this frequency. If US patients with OAG do not receive visual field tests frequently enough, interventions to increase this frequency or to develop other forms of testing visual function may reduce unidentified OAG vision loss.

Design: Retrospective cohort study

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This article contains additional online-only material. The following should appear onlineonly: Tables 1, 2, and 3. Supplemental material is available at https://www.ophthalmologyglaucoma.org

Meeting Presentation: This work has not been presented at a meeting.

Participants: The TruvenHealth MarketScan Commercial Claims Database (IBM, Armonk, NY) contains demographic and claims data for >160 million individuals across the US from 2008–2017. We identified enrollees in the database with a recorded diagnosis of OAG (ICD-9-CM codes: 356.1x; ICD-10-CM codes: H40.1x). We excluded those younger than 40 at the time of their first OAG diagnosis, those without at least one confirmatory OAG diagnosis at a subsequent visit, and those with <4 years of follow-up data after OAG diagnosis.

Methods: We calculated the number of visual field tests that each enrollee with OAG underwent per year and categorized the enrollees based on the number of visual field tests they underwent per year (0, >0 to <0.9, ≥0.9 to ≤1.1, >1.1 to ≤2.1, >2.1). We used negative binomial regression to investigate which demographic or health variables were associated with the frequency of visual field tests that enrollees with OAG received.

Main Outcome Measures: Frequency of visual field testing among enrollees with OAG.

Results: Of the 380,029 enrollees included in the study, 8.8% (33,267) did not receive a visual field test during the study period, 68.2% (259,349) underwent >0 to <0.9 visual field tests per year, 11.1% (42,129) underwent ≥0.9 to ≤1.1 visual field tests per year, 11.1% (42,301) underwent >1.1 to ≤2.1 visual field tests per year, and 0.8% (2,983) underwent ≥2.1 visual field tests per year. The median number of visual field tests per year was 0.63 (IQR:0.33–0.88, mean:0.65).

Conclusions: More than three-quarters of enrollees with OAG received less than one visual field test per year and thus did not receive guideline-adherent glaucoma monitoring.

Abstract

In this large, nation-wide US dataset, more than three-quarters of enrollees with open angle glaucoma received less than one visual field test per year and thus did not receive guidelineadherent glaucoma monitoring.

Introduction

Of patients actively treated for open angle glaucoma (OAG), 5–30% continue to have significant visual field loss and need additional management to lower eye pressure.[1–3] Timely identification of these individuals is essential to prevent blindness from OAG.[4] To identify patients who are being treated for OAG and continue to have progressive visual field loss, visual function is periodically monitored using visual field tests.[5] The ability of these periodic visual field tests to accurately identify vision loss depends on a combination of factors including the number of tests over a given time period, the variability of the measurements, and the rate of vision loss.[6] Testing that isn't frequent enough results in delayed identification of progression of OAG and vision loss.[6–9] The American Academy of Ophthalmology recommends visual field testing at least annually,[5] and additional research suggests that even annual testing may not be frequent enough for many individuals.[9]

Although we know patients with OAG need at least annual visual field tests, we do not know how frequently patients with OAG across the US undergo this testing. A 2013 paper found that patients with OAG in the UK received an average of 0.7 visual field tests per year.[7] A paper looking at 395 patients with glaucoma in the US using data from 1997–1999 found that 40% of patients with moderate to severe glaucoma received visual field tests less

often than every year.[10] The likelihood of a patient with OAG undergoing visual field testing decreased from 2001 to 2009.[11] Understanding how frequently patients with OAG across the US undergo visual field testing will allow us to determine if this testing is done frequently enough and if a significant number of patients are at risk of unidentified vision loss due to infrequent testing.

The purposes of this study were to identify how frequently patients with OAG across the US undergo visual field testing and to evaluate how patient characteristics and circumstances influence this frequency. To accomplish this, we used a US nation-wide claims database with data on more than 1.5 million unique patients with OAG.

Methods

This study was reviewed by the University of Utah Institutional Review Board and deemed exempt as it used de-identified claims data. It adhered to the tenets of the Declaration of Helsinki.

Data Source

The TruvenHealth MarketScan Commercial Claims Database (IBM, Armonk, NY) contains a large, nationwide sample of claims data from 2008–2017 for privately and publicly insured patients. This database has been previously used to study eye care delivery.[12–14] TruvenHealth MarketScan combines a commercial database and a supplemental Medicare database. It contains demographic and claims data for >160 million individuals from 260 employers, 40 health plans, and government and public organizations across the United States.[15] For each enrollee, the claims database includes demographic information (age, sex, urban vs rural home address) and detailed information about each clinical encounter: date and setting of service, provider type, International Classification of Diseases 9th and 10th revision Clinical Modification (ICD-9-CM and ICD-10-CM) diagnosis and procedure codes, and Current Procedural Terminology 4th edition (CPT) codes.

Analysis Sample

We identified all enrollees in the database with a recorded diagnosis of OAG (ICD-9-CM codes: 356.1x; ICD-10-CM codes: H40.1x). We excluded patients under the age of 40 at the time of their first OAG diagnosis. We excluded patients who did not have at least one confirmatory OAG diagnosis at a subsequent visit.[16] To ensure a more accurate estimate of the frequency of visual field testing for each patient, we excluded patients with <4 years of follow-up data after OAG diagnosis.

Variable Definitions

We identified the number of times each enrollee in the sample population underwent a visual field test (CPT code: 92083). We determined if each enrollee had received a diagnosis of macular degeneration or diabetic retinopathy in addition to OAG (ICD-9-CM and ICD-10-CM codes listed in Table 1, available at https://www.ophthalmologyglaucoma.org). In an effort to estimate OAG severity, we determined if each enrollee underwent incisional glaucoma surgery (CPT codes listed in Table 2, available at https://

www.ophthalmologyglaucoma.org) and the number of glaucoma medication classes that the enrollee received (medication types and National Drug Code numbers listed in Table 3, available at https://www.ophthalmologyglaucoma.org).

Statistical Analysis

We calculated the number of visual field tests that each enrollee with OAG underwent per year. We categorized the enrollees into groups based on the number of visual field tests they underwent per year (0, >0 to <0.9, ≥0.9 to ≤1.1, >1.1 to ≤2.1, >2.1). These ranges were determined a priori, with ≥0.9 to ≤1.1 chosen to serve as an approximation for annual testing, which is the recommendation from the American Academy of Ophthalmology. Within each group we summarized demographic and comorbidity information. We conducted subgroup analyses for (1) the population excluding the oldest quartile of enrollees, (2) those enrollees who did not receive glaucoma medications or incisional surgery, and (3) those enrollees who received at least one glaucoma medication or incisional surgery. We calculated the median number of visual field tests per year for these subgroups.

To investigate which demographic or health variables were associated with the number of visual field tests that enrollees with OAG received per year, we ran a negative binomial regression of count of visual field tests modeled against age at first OAG diagnosis, sex, urban vs rural residence, diabetic retinopathy, macular degeneration, number of types of glaucoma drops prescribed, receipt of incisional glaucoma surgery, and year of care. Person-months from the date of initial glaucoma diagnosis until the last date of enrolment were included as an additional variable in the regression model as an offset to account for the time each enrollee was eligible to undergo a visual field test.

To investigate the association of enrollee eyecare provider type (optometrist vs ophthalmologist) on the number of visual fields an enrollee received per year, we broke each patient's enrollment period into calendar years and noted the number of visual field tests the patient underwent that year. We flagged whether the patient had a claim filed for a clinic visit by an optometrist, ophthalmologist, or both that year. We then restricted our data set to only those years when a patient saw a single provider type. The number of visual field tests received was modeled against provider type seen as well as the same cofactors used in the previous model in generalized estimating equation models with a negative binomial distribution clustered on enrollee. However, since our models now included a separate data point for each year, age and incisional glaucoma surgery were treated as time-varying covariates. Incisional glaucoma surgery was coded as whether the patient had received the surgery that year or in any year prior. Person-months were included as an offset. All analyses were conducted using R (R version 4.1.3, R Foundation for Statistical Computing, Vienna, Austria).

Results

We identified 1,585,847 enrollees in the database who had a diagnosis of OAG. Of these, 62,235 (3.93%) were excluded because they were younger than age 40 at first diagnosis, 349,212 (22.03%) were excluded because they only received one claim with an OAG diagnosis during the enrollment period, and 1,146,836 (72.36%) were excluded because they

had less than four years of follow-up in the database; 353,465 (22.3%) individuals met more than one exclusion criteria. After applying these exclusion criteria, 380,029 enrollees made up our study population. The median age in our study population was 67 (inter-quartile range [IQR]: 57–77) and most were female (207,432 [54.58%]). Table 4 presents the full descriptive characteristics of the study population.

In this sample of older adults with OAG more than 4 years of follow-up, 8.75% (33,267) did not undergo a visual field test during the study period, 68.24% (259,349) underwent >0 to <0.9 visual field tests per year, 11.09% (42,129) underwent ≥0.9 to ≤1.1 visual field tests per year, 11.13% (42,301) underwent >1.1 to ≤2.1 visual field tests per year, and 0.78% (2,983) underwent >2.1 visual field tests per year (Table 4). Overall, the median number of visual field tests per year was 0.63 (IQR: 0.33–0.88, mean: 0.65). For those enrollees who received incisional glaucoma surgery, the median number of visual field tests per year was 0.86 (IQR: 0.60–0.1.17). For the subgroup excluding the oldest quartile of enrollees, the median number of visual field tests per year was 0.67 (IQR: 0.40–0.89, mean: 0.68). For the subgroup of those enrollees who did not receive glaucoma medications or incisional surgery, the median number of visual field tests per year was 0.56 (IQR: 0.20–0.80, mean: 0.56). For the subgroup of those enrollees who received at least one glaucoma medication or incisional surgery, the median number of visual field tests per year was 0.67 (IQR: 0.40–0.89, mean: 0.68).

To evaluate the association of demographic and health variables with the number of visual field tests that enrollees with OAG received per year, we ran a negative binomial regression (results in Table 5). Older age (incident rate ratio [IRR]: 0.994 per year of age; 95% confidence interval [CI]: 0.994–0.995; p<0.001), female sex (IRR: 0.989; 95%CI: 0.985–0.993; p<0.001), and having a diagnosis of diabetic retinopathy (IRR: 0.929; 95%CI: 0.920–0.937; p<0.001) were associated with receiving visual field tests less frequently. Using more glaucoma medications (IRR for ≥3 medication classes compared to 0 medication classes: 1.397; 95%CI: 1.388–1.406; p<0.001), living in an urban rather than rural setting (IRR: 1.089; 95%CI: 1.083–1.096; p<0.001), receiving incisional glaucoma surgery (IRR: 1.194; 95%CI: 1.188–1.201; p<0.001), and having a diagnosis of macular degeneration (IRR: 1.038; 95%CI: 1.033–1.044; p<0.001) were associated with receiving visual field tests more frequently. In this adjusted model, enrollees who received three or more glaucoma medication types underwent 39.7% (95% CI: 38.8%–40.6%; p<0.001) more visual field tests per year than those who did not receive any glaucoma medications. Enrollees who received incisional glaucoma surgery underwent 19.4% (95% CI: 18.8%–20.1%; p<0.001) more visual field tests per year than those who did not receive incisional glaucoma surgery. Receiving care in later years was associated with receiving fewer visual fields (IRR: 0.961 per year; 95% CI: 0.960–0.962; p<0.001).

To evaluate the association of enrollee eyecare provider type (optometrist vs ophthalmologist) on the number of visual fields an enrollee underwent per year, we ran a negative binomial regression using the restricted dataset of only those years where a patient saw a single provider type (results in Table 6). Enrollees who saw only an ophthalmologist in a given year were more likely to undergo visual field tests than enrollees who saw only an optometrist in a given year (IRR: 1.24 [95% CI: 1.24–1.25; P<0.001]), even though the

model was adjusted for the number of glaucoma medication classes received and whether or not the patient had undergone incisional glaucoma surgery. In this adjusted model, enrollees who saw only an ophthalmologist in a given year underwent 24.3% (95% CI: 23.8%–24.8%; p<0.001) more visual field tests in that year than enrollees who saw only an optometrist in a given year.

Discussion

In this large, nation-wide US dataset, enrollees with OAG only received a median of 0.63 visual field tests per year (IQR: 0.33–0.88, mean: 0.65). The American Academy of Ophthalmology guidelines recommend that visual field testing be performed at least annually.[5] In this study population, more than 77% of enrollees with OAG did not receive annual visual field testing and thus did not receive guideline-adherent glaucoma monitoring. Although individual patient characteristics and circumstances may make less frequent visual field testing appropriate in some patients, it is striking that more than three-quarters of the enrollees in this nationwide population did not meet visual field testing guidelines. Inadequate testing leads to delayed identification of progression of OAG and vision loss.[6–9]

Our finding that more than three-quarters of the enrollees in this nationwide population did not meet visual field testing guidelines has implications for both individual patient care and US population health. Clinicians caring for patients with glaucoma should evaluate their personal practice patterns and recognize that there is a nationwide bias toward insufficient testing. Difficulties with insurance reimbursement for visual fields, patient preference, and provider convenience may contribute to this.[6,17] From a US population perspective, this level of inadequate testing could lead to considerable unidentified preventable vision loss and blindness.[6] We found that more than three-quarters of those with OAG did not meet visual field testing guidelines. The actual proportion of people with OAG in the US who do not receive visual field testing frequently enough may be much higher because our study only included patients with health insurance who had specifically received care for OAG with at least two clinic visits for OAG and with at least 4 years of enrollment in their health plan.

We found that enrollees who did not receive glaucoma medications or incisional surgery underwent 0.56 (IQR: 0.20–0.80, mean: 0.56) visual field tests per year while those that received at least one glaucoma medications or incisional surgery underwent 0.67 (IQR: 0.40–0.89, mean: 0.68) visual field tests per year. It is possible that enrollees with very mild or stable glaucoma that did not require treatment were being appropriately spaced out to have visual field tests less frequently. However, it is concerning that even among enrollees who were treated for glaucoma (either with medications or surgery) more than 75% had fewer than one visual field test per year and thus did not receive guideline-adherent glaucoma monitoring. An important limitation of this subgroup analysis is that it is impossible to know from the claims data if the enrollees who didn’t receive glaucoma medication or undergo incisional surgery were receiving appropriate treatment. It is possible that they actually needed treatment and visual field test monitoring but were not receiving it.

The frequency of visual field testing should vary based on patient characteristics and circumstances.[5] Many patients may need visual field testing more often than annually.[5,6,8] In our study population, younger age, male sex, living in an urban area, using more medication glaucoma medication classes, having glaucoma incisional surgery, and seeing only an ophthalmologist rather than an optometrist in a given year were associated with receiving visual field tests more frequently. Some of this variation, such as male sex and living in an urban area, is likely unwarranted and may represent biases and barriers in healthcare delivery. Some of this variation, such as using more medications and having glaucoma incisional surgery (as markers of more severe glaucoma), is likely warranted. Prior work suggests that much more variation in testing frequency may be necessary for timely identification of glaucoma progression in certain patients.[6,8,9,18] Interventions, such as clinical decision support systems to aid clinicians as they make eye care decisions, may help clinicians determine the appropriate testing frequency for individual patients.[19,20]

Visual fields may not be performed often enough because they can be burdensome for patients and require significant resources to perform.[6,17] Innovations to improve visual field testing, such as faster testing algorithms and virtual reality field monitoring, could make more frequent visual field testing more feasible and less burdensome for patients.[21–23] Visual fields may not be performed often enough because of a trend towards increased use of optic nerve imaging.[11] A previous study showed that the odds of patients with glaucoma undergoing visual field testing decreased while the odds of undergoing optic nerve imaging increased from 2001 to 2009.[11] We found that the frequency of visual field testing decreased over time from 2008–2017 (IRR: 0.961 per year; 95% CI: 0.960–0.962; $p<0.001$), though our study was not designed to evaluate the use of OCT.

In our study population, enrollees who saw only an ophthalmologist in a given year underwent 24.3% (95% CI: 23.8%–24.8%; $p<0.001$) more visual field tests in that year than enrollees who saw only an optometrist in a given year. It is possible that enrollees who saw only an optometrist in a given year had less severe glaucoma and thus needed visual field testing less frequently. However, the difference in testing frequency was still present even after adjusting for the number of glaucoma medication classes received and whether or not the patient underwent incisional glaucoma surgery (markers of disease severity). Other possible explanations for the difference in the frequency of visual field testing between the two provider types include differences in visual field test availability, reimbursement, practice habits, and experience with glaucoma. Optometrists and ophthalmologists should coordinate care to ensure that patients are receiving visual field testing frequently enough for timely identification of glaucoma progression.

Our study has limitations. The MarketScan Commercial Claims Database does not contain data on important socioeconomic characteristics such as race and income. It is likely that these characteristics contribute to differences in visual field testing frequency.[24] The database only contains claims data; it does not contain actual clinical data and visual field test results. We were not able to directly determine glaucoma severity nor were we able to consistently determine glaucoma severity from the ICD coding. We used markers such as the number of glaucoma medication classes an enrollee received and whether or not a patient underwent incisional glaucoma surgery to judge the influence of glaucoma severity

on the frequency of visual field testing. We were not able to determine if patients were appropriately receiving visual field tests less frequently for individual circumstances that were not included in the database (such as patient preference or profound vision loss) or whether they had visual field tests that were paid for out-of-pocket or through a different insurer. Our database did not consistently identify the individual provider providing care so we were not able to evaluate the impact of an individual provider's practice patter on the frequency of visual field testing.

In this US nation-wide cohort of 380,029 patients with OAG, more than three-quarters of the enrollees in this nationwide population did not meet annual visual field testing guidelines. This could lead to a considerable delay in the identification of OAG progression and subsequent unnecessary vision loss. Interventions, such as clinical decision support systems and innovations in visual field testing, could address this shortcoming in US OAG care.[19,21–23] Clinicians caring for patients with glaucoma should evaluate their personal practice patterns and recognize that there is a nationwide bias toward insufficient testing.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Financial Support:

This work was supported by National Institutes of Health (R01EY026641 to JDS, R01EY029885 to FAM, R01EY015130 and R01EY017011 to MEH), an Unrestricted Grant from Research to Prevent Blindness, New York, NY, to the Department of Ophthalmology & Visual Sciences, University of Utah (BCS and MEH) and the Department of Ophthalmology & Visual Sciences, University of Michigan (JDS), and a Mentoring for the Advancement of Physician Scientists (MAPS) grant from the American Glaucoma Society, San Francisco, California. The funding organizations had no role in the design or conduct of this research.

Conflict of Interest:

FAM reports grants from National Eye Institute, during the conduct of the study; personal fees from Aeri Pharmaceuticals, personal fees from Allergan, personal fees from Novartis, personal fees from Biogen, personal fees from Galimedix, personal fees from Annexon, grants from Google, Inc, grants from Carl-Zeiss Meditec, personal fees from Heidelberg Engineering, personal fees from Stuart Therapeutics, personal fees from IDx, personal fees from Reichert. JDS reports a research grant from Abbvie, outside the submitted work.

The other authors have no conflicts related to the proposed work to report.

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Table 4.

Descriptive characteristics of the study population, stratified by the frequency of undergoing visual field testing. Categorical variables presented as counts (%), continuous variables presented as median (intra-quartile range).

	0 VFT/year	**>0 to <0.9 VFT/ year**	**≥0.9 to ≤1.1 VFT/year**	**>1.1 to ≤2.1 VFT/year**	**>2.1 VFT/year**	**Full cohort**
N	33267 (8.75%)	259349 (68.24%)	42129 (11.09%)	42301 (11.13%)	2983 (0.78%)	380029 (100%)
Age	73 (59–82)	67 (57–77)	66 (57–75)	66 (58–75)	66 (57–74)	67 (57–77)
Sex						
Female	19221 (57.78%)	141579 (54.59%)	22308 (52.95%)	22771 (53.83%)	1553 (52.06%)	207432 (54.58%)
Male	14046 (42.22%)	117770 (45.41%)	19821 (47.05%)	19530 (46.17%)	1430 (47.94%)	172597 (45.42%)
Residence location						
Rural	5542 (16.66%)	36190 (13.95%)	5331 (12.65%)	4512 (10.67%)	280 (9.39%)	51855 (13.65%)
Urban	27725 (83.34%)	223159 (86.05%)	36798 (87.35%)	37789 (89.33%)	2703 (90.61%)	328174 (86.35%)
Ocular comorbidities						
Diabetic retinopathy	2789 (8.38%)	18424 (7.1%)	2494 (5.92%)	2705 (6.39%)	181 (6.07%)	26593 (7%)
Macular degeneration	8154 (24.51%)	50501 (19.47%)	8201 (19.47%)	9263 (21.9%)	710 (23.8%)	76829 (20.22%)
Number of types of glaucoma medications prescribed						
0	11732 (35.27%)	65855 (25.39%)	8151 (19.35%)	7832 (18.51%)	557 (18.67%)	94127 (24.77%)
1	10747 (32.31%)	88819 (34.25%)	12651 (30.03%)	9594 (22.68%)	467 (15.66%)	122278 (32.18%)
2	6128 (18.42%)	56261 (21.69%)	9996 (23.73%)	9406 (22.24%)	537 (18%)	82328 (21.66%)
≥3	4660 (14.01%)	48414 (18.67%)	11331 (26.9%)	15469 (36.57%)	1422 (47.67%)	81296 (21.39%)
Receipt of incisional glaucoma surgery						
Yes	381 (1.15%)	6604 (2.55%)	1964 (4.66%)	3414 (8.07%)	378 (12.67%)	12741 (3.35%)

VFT=Visual field tests

Table 5.

Results of negative binomial regression evaluating the association of demographic and health variables with the number of visual field tests that enrollees with open angle glaucoma (OAG) received per year.

Cofactor	Incident rate ratio[a]	Low 95% CI	High 95% CI	P value
Age (per each year older)	0.994	0.994	0.995	<0.001
Sex				
Male	Reference			
Female	0.989	0.985	0.993	<0.001
Macular degeneration[b]	1.038	1.033	1.044	<0.001
Diabetic retinopathy[c]	0.929	0.920	0.937	<0.001
Number of glaucoma medication classes received				
None	Reference			
1	1.103	1.096	1.110	<0.001
2	1.218	1.210	1.226	<0.001
≥3	1.397	1.388	1.406	<0.001
Location of residence				
Rural	Reference			
Urban	1.089	1.083	1.096	<0.001
Year of care				
Each additional year	0.961	0.960	0.962	<0.001
Undergoing incisional glaucoma surgery				
No	Reference			
Yes	1.194	1.188	1.201	<0.001

[a]Incident rate ratio = The adjusted ratio of the number of visual field tests for each of the cofactors listed above compared to the reference group for that cofactor. A higher incidence rate ratio indicates that patients with that cofactor received more visual field tests than those in the reference group.

[b]Reference group is those without macular degeneration.

[c]Reference group is those without diabetic retinopathy.

Table 6.

Results of negative binomial regression evaluating the association of enrollee eyecare provider type (optometrist vs ophthalmologist) with the number of visual field tests that enrollees with open angle glaucoma (OAG) received per year using the restricted dataset of only those years where a patient saw a single provider type.

Cofactor	Incident rate ratio[a]	Low 95% CI	High 95% CI	P value
Enrollee eyecare provider type				
Only optometrist	Reference			
Only ophthalmologist	1.243	1.238	1.248	<0.001
Age (per each year older)	0.994	0.994	0.995	<0.001
Sex				
Male	Reference			
Female	0.986	0.982	0.990	<0.001
Macular degeneration[b]	1.026	1.021	1.032	<0.001
Diabetic retinopathy[c]	0.921	0.913	0.929	<0.001
Number of glaucoma medication classes received				
None	Reference			
1	1.098	1.091	1.104	<0.001
2	1.202	1.194	1.209	<0.001
≥3	1.365	1.356	1.373	<0.001
Location of residence				
Rural	Reference			
Urban	1.067	1.060	1.073	<0.001
Year of care				
Each additional year	0.965	0.964	0.965	<0.001
Undergoing incisional glaucoma surgery				
No	Reference			
Yes	1.170	1.164	1.176	<0.001

[a] Incident rate ratio = The adjusted ratio of the number of visual field tests for each of the cofactors listed above compared to the reference group for that cofactor. A higher incidence rate ratio indicates that patients with that cofactor received more visual field tests than those in the reference group.

[b] Reference group is those without macular degeneration.

[c] Reference group is those without diabetic retinopathy.