

A Comparison of Resource Use and Costs of Caring for Patients With Exfoliation Syndrome Glaucoma Versus Primary Open-Angle Glaucoma



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• **PURPOSE:** To characterize differences in resource utilization and cost of managing enrollees with exfoliation glaucoma (XFG) compared to primary open-angle glaucoma (POAG).

• **DESIGN:** Retrospective utilization and cost comparison using Medicare claims data.

• **METHODS:** We identified Medicare beneficiaries with XFG or POAG and ≥ 5 years of continuous enrollment from January 2008 to December 2014. We distinguished newly diagnosed cases from those with preexisting disease. We compared ophthalmic resource utilization and costs over 2 years of follow-up for persons with newly diagnosed and preexisting XFG vs those with POAG. Main outcome measures were number of clinic visits, diagnostic procedures, medication fills, laser and incisional surgery, and mean eye care costs per beneficiary.

• **RESULTS:** Among 192 eligible enrollees (median age 77.6 years) with newly diagnosed XFG and 7339 enrollees (median age 77.3 years) with newly diagnosed POAG, those with XFG had more office visits (mean, 9.1 vs 7.9; $P = .001$), cataract surgery (34.9% vs 19.0%; $P < .0001$), and glaucoma surgery (28.7% vs 19.7%, $P = .002$). They also experienced 27% higher mean total eye care costs (\$3260 vs \$2562, $P = .0001$) over 2 years of follow-up. Among 2745 enrollees (median age 80.5 years) with preexisting XFG and 89 036 persons (median age 79.5) with preexisting POAG, persons with XFG had more office visits (mean 9.3 vs 7.3; $P < .0001$), perimetry (85.3% vs 79.8%; $P < .0001$), cataract surgery (23.4% vs 12.3%; $P < .0001$), laser trabeculoplasty (18.6% vs 9.6%;

$P < .0001$), and trabeculectomy (8.1 vs 1.8%; $P < .0001$) and experienced 37% higher total mean eye care costs (\$3764 vs \$2739; $P < .0001$).

• **CONCLUSIONS:** Healthcare resource utilization and costs are substantially higher for managing patients with XFG compared to POAG. (Am J Ophthalmol 2019;200:100–109. © 2019 Elsevier Inc. All rights reserved.)

WITH THE PASSAGE OF THE AFFORDABLE CARE Act and, more recently, the Medicare Access and CHIP Reauthorization Act legislation, health policymakers have been looking for alternative models for provider reimbursement, such as those that involve bundling of payments for healthcare services into episodes of care instead of the traditional fee-for-service (FFS) payment approach. Unlike traditional FFS reimbursement, which incentivizes increased resource utilization, bundled payment designs provide clinicians a single payment to cover all services related to a specific condition or treatment over a specified time period. The acceptability of these alternative payment models to patients and healthcare providers requires that such models are capable of accounting for disease severity and complexity when determining proper payment for a given bundle or episode of care. For example, if insurers were to create a bundled payment for glaucoma care such that providers are allocated the same payment amount for patients with all types, severities, and complexities of glaucoma, this could incentivize eye care providers to perform additional and potentially unnecessary testing and treatment to some patients with less severe disease, while at the same time it could also incentivize them to undertreat other patients with more complex or severe disease, since the payment is the same for all patients. By identifying differences in resource utilization and costs for patients with different types or levels of disease, insurers can factor this into the amount of payment for an episode or bundle of care such that it promotes high-value, cost-effective care.

Resource use and costs, and how they vary by disease severity, have been characterized for patients with primary open-angle glaucoma (POAG).^{1–5} For example, Lee and associates demonstrated that the mean direct annual

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medical costs of caring for patients with mild-stage glaucoma were nearly 4-fold lower than for other patients with very advanced disease.¹ Likewise, Pasquale and associates found that patients with ocular hypertension accrued much lower annual charges relative to others with POAG.² Yet little is known about the extent to which resource utilization and costs vary for patients with one type of glaucoma vs another and for those with newly diagnosed (incident) disease vs patients with preexisting (prevalent) disease.

Exfoliation syndrome glaucoma (XFG) is the most common secondary open-angle glaucoma. Similar to POAG, this condition often affects both eyes but can be very asymmetric. Patients with XFG are known to experience higher peak intraocular pressure (IOP),⁶⁻¹⁰ more rapid visual field deterioration,⁶⁻⁸ higher rates of failure of medical therapies, and more frequent need for surgical interventions compared to patients with POAG.^{6,11,12} Therefore, we hypothesize that patients with XFG experience greater resource utilization and costs compared to persons with POAG, though the extent to which differences in resource use and costs exist is unknown. Thus, the purpose of this study is to compare resource utilization and costs of managing Medicare beneficiaries with XFG to those with POAG and whether differences in ophthalmic resource utilization and total eye care costs are different for those with newly diagnosed disease vs others who have had the conditions for a while.

METHODS

- **DATA SOURCE:** We used a Medicare claims dataset consisting of a nationally representative 20% sample of all persons with Medicare Parts A, B, and D health insurance coverage from January 1, 2008 to December 31, 2014. The database contains detailed records of all ocular and nonocular conditions based on International Classification of Disease, 9th Revision - Clinical Modification¹³ (ICD-9-CM) billing codes and all visits, diagnostics, and therapeutic procedures based on Current Procedural Terminology¹⁴ (CPT-4) codes. Since all eligible patients had Part D coverage, we were able to capture all outpatient medications filled during the study period as well. The database also contains information on demographics, type of healthcare provider for each encounter, and amount paid for all services rendered. Researchers have used this database in the past to study patients with glaucoma and other ocular conditions,^{4,15} and the study was approved by the Institutional Review Board at the University of Michigan.

- **STUDY PARTICIPANTS/INCLUSION AND EXCLUSION CRITERIA:** We identified all eligible enrollees with records of XFG (ICD-9-CM: 365.52) or POAG (ICD-9-CM:

365.10-365.15) from January 1, 2011 to December 31, 2012. To help ensure that the patient was not miscoded as one of these conditions, we required eligible enrollees to have ≥ 1 confirmatory diagnosis of the condition on a separate date. If an enrollee received diagnoses of both POAG and XFG, he or she was classified as XFG. To be more certain these persons had bona fide XFG or POAG and were not glaucoma suspects or “rule out” cases, we excluded those who had been diagnosed with either of these conditions but had no record of any medical, laser, or surgical interventions for glaucoma. Other inclusion criteria for this analysis were age at plan enrollment of ≥ 65 years, continuous enrollment in FFS Medicare for at least 5 years, Part D coverage for outpatient medication prescriptions for all 5 years, and ≥ 2 visits to an eye care provider (ophthalmologist or optometrist). We excluded beneficiaries residing outside the United States, persons with missing demographic information, and persons in Medicare Advantage plans. Individuals in Medicare Advantage plans were excluded, since the database does not contain complete data of all healthcare services rendered for these enrollees.

- **DISTINGUISHING BENEFICIARIES WITH NEWLY DIAGNOSED VS PREEXISTING PRIMARY OPEN-ANGLE GLAUCOMA AND EXFOLIATION GLAUCOMA:** To identify persons with newly diagnosed (incident) XFG or POAG, we required them to have no record of these conditions during their first 3 years in the health plan and ≥ 1 visit to an eye care provider during that period to give each person an opportunity to get diagnosed with these conditions. Since distinguishing POAG from XFG can be challenging after cataract surgery, we excluded persons who were pseudophakic or aphakic during their first 3 years in the plan. Persons who were diagnosed with other forms of glaucoma besides XFG or POAG during their first 3 years in the plan were also excluded, though enrollees who were classified as glaucoma suspects (ICD9: 365.00, 365.01, 365.04) or XFG suspect (ICD9-366.11) during this time period were not excluded and were thus eligible to be classified as incident cases during the follow-up period. Incident cases of XFG or POAG required 1 or more confirmatory diagnosis on a separate date during the follow-up period for inclusion. Enrollees with ≥ 1 record of XFG or POAG during their first 3 years in the plan were categorized with preexisting disease (prevalent cases) and were included if they also had 1 or more confirmatory diagnosis of the condition during the follow-up period (Figure 1).

- **RESOURCE USE AND COSTS:** The outcome of interest was ophthalmic resource use and total eye care costs during a 24-month period. This 24-month period included the date of initial diagnosis of XFG or POAG. Resource use was identified by CPT billing codes and grouped into the following categories: visits to eye care providers; diagnostic procedures to monitor glaucoma (perimetry, fundus

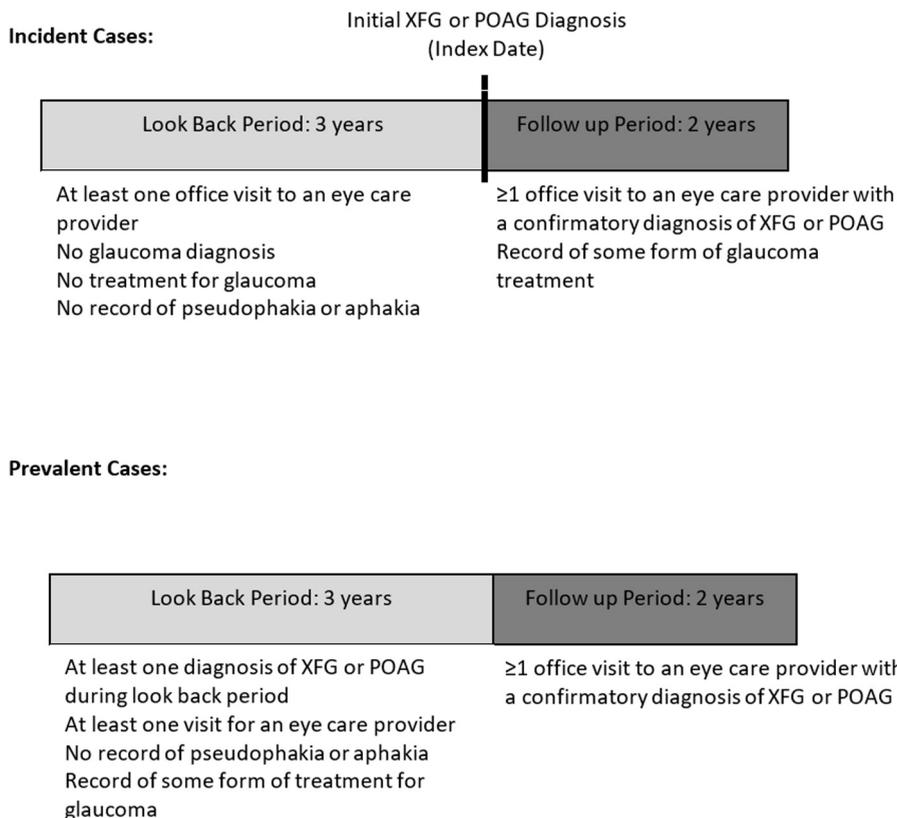


FIGURE 1. Sample selection criteria to identify enrollees with incident and prevalent exfoliation syndrome glaucoma (XFG) and primary open-angle glaucoma (POAG).

photography, other ocular imaging [ie, optical coherence tomography (OCT)], gonioscopy, other glaucoma diagnostic tests); laser and incisional glaucoma surgery; cataract surgery; and outpatient prescription fills for the following classes of glaucoma medications: topical beta blockers, oral and topical carbonic anhydrase inhibitors, prostaglandin analogues, parasympathomimetics, and alpha agonists. The [Supplemental Table](#) (Supplemental Material available at [AJO.com](#)) lists the specific CPT codes included in the analysis. We also looked at the mean costs of each of these services and how they varied for enrollees with XFG vs POAG over the 24-month follow-up period. Mean costs for each category were calculated by dividing the total cost for each of the resource categories by the number of beneficiaries in the XFG or POAG groups. Dollar value paid by Medicare rather than physician charges were used to calculate cost.

• **ANALYSIS:** Statistical analyses were performed using SAS software version 9.2 (SAS Institute, Cary, North Carolina, USA). Participant characteristics were summarized for the entire sample using means and standard deviations (SD) for continuous variables and frequencies and percentages for categorical variables.

We determined the mean \pm SD number of eye clinic visits, glaucoma diagnostic testing, glaucoma surgeries, and glaucoma medication fills over 24 months of follow-up for those with newly diagnosed XFG and POAG. The mean numbers of each of these services were compared using an unpaired *t* test. We also assessed the proportion of enrollees undergoing these services at least once during the 24 months and used a χ^2 test to compare the groups. We performed similar comparisons for those with preexisting XFG vs those with preexisting POAG. Total eye care costs were calculated as the sum of all costs for eye clinic visits, glaucoma diagnostic testing, glaucoma and cataract surgery, and outpatient glaucoma medication costs over the 24-month period. Comparisons of the mean costs for those with newly diagnosed and preexisting XFG vs POAG were performed using an unpaired *t* test. For all analyses, $P \leq .05$ was considered statistically significant.

RESULTS

THERE WERE 4 541 378 MEDICARE ENROLLEES WHO MET OUR inclusion criteria. Of these individuals, 346 626 patients

TABLE 1. Characteristics of Study Sample

	Incident Cases				Prevalent Cases			
	POAG		XFG		POAG		XFG	
	N	%	N	%	N	%	N	%
Total	7339		192		89 036		2745	
Race/ethnicity								
White	5736	78.2%	187	97.4%	69 114	77.6%	2552	93.0%
Black	809	11.0%	0	0.0%	11 812	13.3%	32	1.2%
Hispanic	272	3.7%	0	0.0%	2824	3.2%	54	2.0%
Asian	319	4.3%	2	1.0%	3286	3.7%	41	1.5%
Native American	28	0.4%	1	0.5%	344	0.4%	12	0.4%
Other	173	2.4%	2	1.0%	1627	1.8%	54	2.0%
Sex								
Male	2603	35.5%	60	31.3%	28 538	32.1%	799	29.1%
Female	4734	64.5%	132	68.8%	60 469	67.9%	1946	70.9%
Median age (years)	77.3		77.6		79.5		80.5	
Comorbid ocular disease								
PDR	81	1.1%	0	0.0%	1244	1.4%	6	0.2%
NPDR	281	3.8%	1	0.5%	3642	4.1%	49	1.8%
AMD	1356	18.5%	32	16.7%	14 681	16.5%	531	19.3%
DME	125	1.7%	1	0.5%	2218	2.5%	47	1.7%
RD	109	1.5%	2	1.0%	1219	1.4%	39	1.4%

AMD = age-related macular degeneration; DME = diabetic macular edema; NPDR = nonproliferative diabetic retinopathy; PDR = proliferative diabetic retinopathy; POAG = primary open-angle glaucoma; RD = retinal detachment; XFG = exfoliation syndrome glaucoma.

Incident cases were patients who had no record of any glaucoma during their first 3 years in the plan and then received a diagnosis of XFG or POAG. Prevalent cases were patients with ≥1 diagnosis of XFG or POAG during their first 3 years in the plan.

had a diagnosis of XFG or POAG between January 1, 2011 and December 31, 2012 and among these, 137 941 had 3 years of lookback data, 2 years of follow-up data, and at least 2 visits to eye care providers. After exclusion of persons who were aphakic or pseudophakic and patients without any record of treatment, 99 312 patients were remaining in our study sample. There were 192 eligible Medicare enrollees who had been diagnosed with incident XFG and 7339 persons with incident POAG. There were also 2745 eligible enrollees with prevalent XFG and 89 036 enrollees with prevalent POAG identified. The median age of those with incident XFG (77.6 years) and POAG (77.3 years) were relatively similar ($P = .32$). The median age of persons with preexisting XFG was 80.5 years and those with preexisting POAG was 79.5 years ($P < .0001$). There were slightly greater proportions of women with XFG compared to POAG (68.8% vs 64.5% for incident cases, $P = .22$ and 70.9% vs 67.9%, $P = .001$ for prevalent cases). Among those with XFG, a greater proportion were white race compared to those with POAG (97.4% vs 78.2% for incident cases, $P < .0001$ and 93.0% vs 77.6% for prevalent cases, $P < .0001$) (Table 1).

• COMPARISON OF OPHTHALMIC RESOURCE USE AND TOTAL EYE CARE COSTS FOR ENROLLEES WITH NEWLY DIAGNOSED EXFOLIATION SYNDROME GLAUCOMA VS

PRIMARY OPEN-ANGLE GLAUCOMA: Eye Clinic Visits/Diagnostic Testing. The mean number of eye clinic visits over the 24-month follow-up period was higher for enrollees with newly diagnosed XFG compared to those with POAG (XFG: 9.1 eye visits per patient over the 2 years; POAG: 7.9 eye visits per patient over the 2 years), $P = .001$. Nearly all enrollees in both groups underwent some form of glaucoma diagnostic testing over the 24 months (98.4% for those with XFG vs 97.0% for enrollees with POAG, $P = .25$), though enrollees with XFG underwent a greater number of glaucoma diagnostic tests (mean: 5.0 for those with XFG vs 4.0 for those with POAG, $P < .0001$) over the 24-month follow-up period. In terms of specific glaucoma diagnostic tests, a greater proportion of persons with newly diagnosed XFG underwent gonioscopy (54.7% vs 37.0%; $P < .0001$) and fundus photography (47.9% vs 40.4%, $P = .04$) compared to those with POAG, while there were no statistically significant differences in proportions receiving perimetry (86.5% vs 84.7%; $P = .50$) or other ocular imaging (OCT) (75.5% vs 76.0%; $P = .88$) between the 2 groups (Table 2).

Therapeutic Interventions. Proportionately, slightly more patients with POAG filled at least 1 prescription for glaucoma medications during the 2-year follow-up period

TABLE 2. Ophthalmic Resource Utilization During 2 Years of Follow-Up for Enrollees with Incident and Prevalent Primary Open-Angle Glaucoma and Exfoliation Syndrome Glaucoma

	Incident Cases					Prevalent Cases				
	POAG		XFG		P Value	POAG		XFG		P Value
	N	%	N	%		N	%	N	%	
Total enrollees	7339		192			89 036		2745		
Diagnostic procedures (%)										
Any glaucoma diagnostic test ^a	7121	97.0%	189	98.4%	.25	83 833	94.2%	2657	96.8%	<.0001
Perimetry	6216	84.7%	166	86.5%	.50	71 079	79.8%	2341	85.3%	<.0001
Gonioscopy	2716	37.0%	105	54.7%	<.0001	23 736	26.7%	1082	39.4%	<.0001
Fundus photography	2964	40.4%	92	47.9%	.036	31 115	35.0%	974	35.5%	.56
Other ocular imaging	5577	76.0%	145	75.5%	.88	62 333	70.0%	1964	71.6%	.083
Any other diagnostic test ^b	4156	56.6%	135	70.3%	.0002	46 188	51.9%	1673	61.0%	<.0001
Therapeutic procedures (%)										
Any ocular surgery ^c	3282	44.7%	118	61.5%	<.0001	32 277	36.3%	1495	54.5%	<.0001
Any glaucoma surgery ^d	1443	19.7%	55	28.7%	.002	12 591	14.1%	860	31.3%	<.0001
Trabeculectomy	68	0.9%	4	2.1%	.10	1611	1.8%	233	8.1%	<.0001
GDI	26	0.4%	2	1.0%	.12	889	1.0%	103	3.8%	<.0001
LTP	1120	15.3%	38	19.8%	.086	8585	9.6%	511	18.6%	<.0001
Medication	6839	93.2%	175	91.2%	.27	87 629	98.4%	2680	97.6%	.0012
Cataract surgery	1391	19.0%	67	34.9%	<.0001	10 964	12.3%	643	23.4%	<.0001

GDI = glaucoma drainage implant; LTP = laser trabeculectomy; POAG = primary open-angle glaucoma; XFG = exfoliation glaucoma.

Proportions capture enrollees who underwent 1 or more of a given service during the 2 years of follow-up.

Group comparisons were performed using Pearson χ^2 test.

^aAny glaucoma diagnostic test includes gonioscopy, fundus photography, perimetry, optical coherence tomography.

^bAny other diagnostic test: see Supplemental Table (Supplemental Material available at AJO.com) for included CPT codes.

^cAny ocular surgery includes all laser and incisional ophthalmic surgeries, including but not limited to glaucoma surgeries.

^dAny glaucoma surgery includes laser iridotomy, trabeculectomy, and glaucoma drainage implant insertion.

(93.2%) compared to those with XFG (91.2%) ($P = .27$). However, a considerably greater proportion of patients with newly diagnosed XFG (61.5%) underwent some form of laser or incisional intraocular surgery in the first 24 months after initial diagnosis, compared to those with newly diagnosed POAG (44.7%) ($P < .0001$). The rate of any ocular surgery in the XFG group was 2.0 procedures per patient over the 2 years, compared to 1.3 procedures per patient over the 2 years in the group with POAG ($P = .01$). The most common ocular surgical procedure for persons in both groups was cataract surgery. During the 24 months after initial diagnosis, 34.9% of persons with XFG underwent cataract surgery, compared to 19.0% of those with POAG ($P < .0001$). When all laser and incisional glaucoma surgeries are considered together, a greater proportion of patients with XFG underwent at least 1 of these procedures during the 24 months of follow-up (28.7% vs 19.7%, $P = .002$); however, when we compare proportions undergoing specific surgeries, there were no statistically significant differences in the proportion undergoing laser trabeculectomy (LTP) (19.8% for XFG vs 15.3% for POAG, $P = .09$), trabeculectomy (2.1% for XFG vs 0.9% for POAG, $P = .10$), or glaucoma drainage implant

(GDI) (1.0% for XFG vs 0.4% for POAG, $P = .12$) (Table 2).

Costs. The mean total eye care costs over the 24 months after initial diagnosis for enrollees with newly diagnosed XFG were 27% higher than for persons with newly diagnosed POAG (\$3260 vs \$2562, respectively), $P = .0001$. We found the group with XFG had statistically significantly greater costs for eye clinic visits (\$890 vs \$717, $P = .0001$), glaucoma diagnostic testing (\$523 vs \$378, $P = .0006$), and cataract surgery (\$853 vs \$465, $P = .0001$). There were no significant differences in mean costs of glaucoma surgery (\$276 vs \$235, $P = .47$) or glaucoma medications (\$719 vs \$767, $P = .48$) among the 2 groups (Figure 2).

• COMPARISON OF OPHTHALMIC RESOURCE USE AND TOTAL EYE CARE COSTS FOR ENROLLEES WITH PREVALENT EXFOLIATION SYNDROME GLAUCOMA VS PRIMARY OPEN-ANGLE GLAUCOMA: Eye Clinic Visits/Diagnostic Testing. The mean number of eye clinic visits over the 24-month follow-up period was higher for enrollees with preexisting XFG compared to patients with POAG (XFG: 9.3 eye care visits per patient over the 2 years; POAG: 7.3 eye care visits per patient over the 2 years,

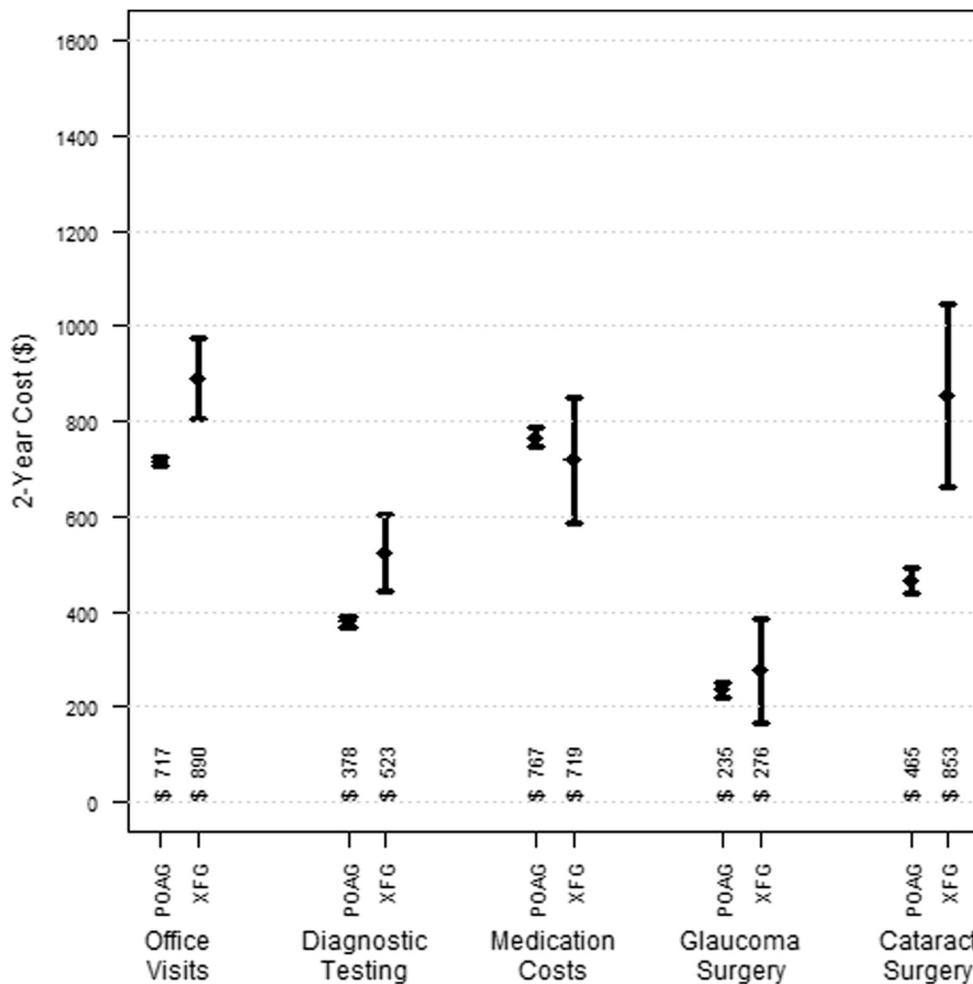


FIGURE 2. Mean total 2-year costs per beneficiary for various diagnostic and therapeutic services for enrollees with newly diagnosed primary open-angle glaucoma (POAG; n = 7339) and exfoliation syndrome glaucoma (XFG; n = 192). $P < .001$ for clinic visit costs; $P < .001$ for glaucoma diagnostic testing costs; $P < .001$ for cataract surgery costs; $P = .46$ for glaucoma surgery costs; $P = .48$ for glaucoma medication costs. Error bars in figure reflect 95% confidence intervals.

$P < .0001$). The majority of the enrollees in both groups underwent some form of glaucoma diagnostic testing over the 24 months (96.8% for those with XFG vs 94.2% for enrollees with POAG, $P < .0001$). Similar to incident cases, enrollees with preexisting XFG underwent a greater number of glaucoma diagnostic tests over the 24-month period (mean, 4.3 tests) compared to those with POAG (mean, 3.7 tests), $P < .0001$. In terms of specific glaucoma diagnostic tests, a greater proportion of persons with prevalent XFG compared to those with POAG underwent gonioscopy (39.4% vs 26.7%; $P < .0001$) and perimetry (85.3% vs 79.8%, $P < .0001$), while there were no statistically significant differences in proportions undergoing fundus photography (35.5% vs 35.0%; $P = .56$) or other ocular imaging (OCT) (71.6% vs 70.0%; $P = .08$) between the 2 groups.

Therapeutic Interventions. Nearly all the patients in both groups had records of at least 1 glaucoma medication fill

during the 2-year follow-up period (97.6% for those with XFG vs 98.4% for those with POAG), $P = .001$. A substantially greater proportion of patients with prevalent XFG (54.5%) underwent some form of laser or incisional intraocular surgery during the 24-month follow-up period compared to those with prevalent POAG (36.3%), $P < .0001$. The rate of any ocular surgery in the XFG group was 1.5 procedures per patient over the 2 years of follow-up compared to 1.0 procedure per patient over the 2 years of follow-up for the group with POAG ($P < .0001$). Similar to those with incident disease, the most common surgical procedure for persons in both groups was cataract surgery. During the 24 months of follow-up, 23.4% of persons with XFG underwent cataract surgery, compared to 12.3% of those with POAG ($P < .0001$). When all laser and incisional glaucoma surgeries were considered together, a greater proportion of patients with XFG underwent at least 1 of these procedures during the 24 months (31.3% vs 14.1%,

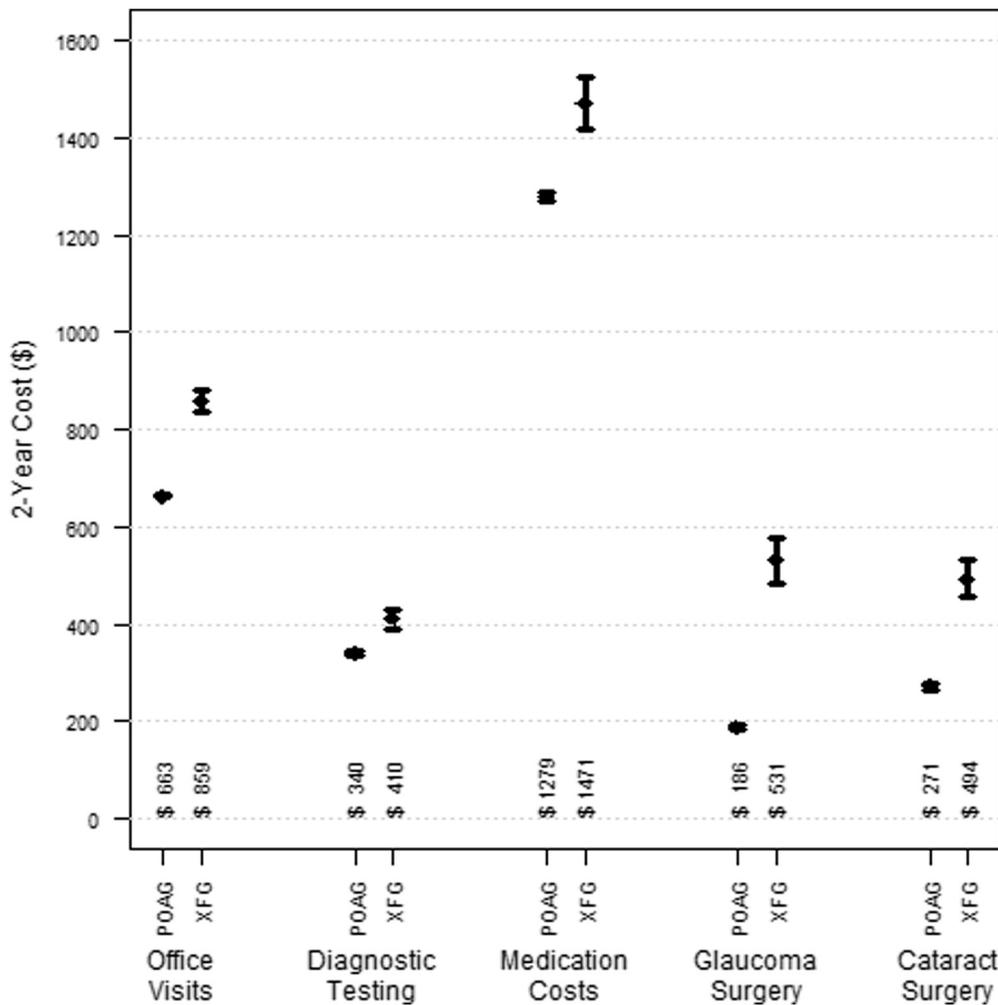


FIGURE 3. Mean total 2-year cost per beneficiary for various diagnostic and therapeutic services for enrollees with preexisting primary open-angle glaucoma (POAG; n = 89 036) and exfoliation syndrome glaucoma (XFG; n = 2745). $P < .0001$ for all cost comparisons. Error bars in figure reflect 95% confidence intervals.

$P < .0001$), and when we assessed specific glaucoma surgeries, we observed greater proportions of persons with XFG undergoing LTP (18.6% vs 9.6%, $P < .0001$), trabeculectomy (8.1% vs 1.8%, $P < .0001$), and GDI insertion (3.8% vs 1.0%, $P < .0001$) (Table 2).

Costs. The mean overall eye care costs over the 24 months for enrollees with prevalent XFG were 37% higher than persons with prevalent POAG (\$3764 vs \$2739, respectively; $P < .0001$), which amounts to more than \$1000 over the 24 months. We found the group with XFG had statistically significantly greater costs of eye clinic visits (\$859 vs \$663, $P < .0001$), glaucoma diagnostic testing (\$410 vs \$340, $P < .0001$), cataract surgery (\$494 vs \$271, $P < .0001$), glaucoma medications (\$1471 vs \$1279, $P < .0001$), and glaucoma surgery (\$531 vs \$186, $P < .0001$) over the 2 years of follow-up (Figure 3).

DISCUSSION

USING DATA FROM A NATIONALLY REPRESENTATIVE SAMPLE of Medicare beneficiaries, we compared resource utilization and total eye care costs for patients with XFG to others with POAG. We learned that for incident cases as well as those with preexisting disease, the group with XFG received more visits to eye care professionals and underwent more diagnostic testing, and a greater proportion received cataract surgery and laser and incisional glaucoma surgery during the 2 years of follow-up, compared to those with POAG. This resulted in nearly \$700 in more total eye care costs for those with incident disease and more than \$1000 in total eye care costs for those with preexisting disease during the follow-up period for those with XFG. While it is well established that patients with XFG tend to be more challenging to manage relative to those with

POAG, these results help quantify the extent of the differences in resource utilization and costs between the groups.

When comparing resource utilization, our findings demonstrate that clinicians similarly manage most patients with newly diagnosed XFG and POAG using perimetry and OCT. However, 1 notable difference in diagnostic testing utilization between the 2 groups was observed for gonioscopy. This may be attributable to clinicians evaluating the drainage angle to help look for evidence to substantiate the diagnosis of XFG (ie, Sampaolesi's line), to assess whether their patients with XFG are candidates for LTP, or to check for narrow angles, which can be associated with XFG.¹⁶ Moreover, a greater proportion of patients with XFG are monitored by glaucoma subspecialists, who may be more apt to perform gonioscopy compared to other eye care providers. Among patients with preexisting disease, we observed a greater preponderance of patients with XFG who underwent perimetry compared to those with preexisting POAG. Patients with XFG may have more severe disease⁸ and thus require more intensive monitoring with perimetry to check for disease progression compared to their counterparts with POAG.

In terms of therapeutic procedures, in our analyses, more than one quarter of the patients with newly diagnosed XFG underwent laser or incisional glaucoma surgery in at least 1 eye and more than one third of them underwent cataract surgery during their first 2 years following XFG diagnosis. These proportions were much higher for both glaucoma and cataract surgery relative to enrollees with newly diagnosed POAG. Patients with XFG may present with denser cataracts,^{17,18} or clinicians may recommend surgery earlier in the course of the disease for those with XFG¹⁹ to try to reduce the risk of complications associated with delaying surgery until the cataract is more mature. Among those with preexisting disease, the proportions who underwent LTP and cataract surgery were approximately double and the proportions who underwent trabeculectomy or GDI were 4-fold higher in the XFG cohort. These differences in utilization translated into much greater costs to manage those with XFG.

When comparing costs of glaucoma care for the 2 groups, we identified several salient findings. In the first 2 years following initial diagnosis, patients with XFG experienced more costs associated with eye clinic visits, glaucoma diagnostic testing, and cataract surgery but no significant difference in costs for glaucoma medications or glaucoma surgery. For those with preexisting disease, the group with XFG had greater costs not only for eye clinic visits and glaucoma diagnostic testing, but also for glaucoma medications and surgery. This suggests that it becomes more challenging and costly to manage patients with XFG over time. If the disease trajectory is more rapid for patients with XFG,⁸ and a greater proportion progress from mild to severe disease, this would in turn affect costs.²⁰ Patients with XFG may also have more difficult-to-control IOP^{6,7,10} or larger fluctuations in IOP,^{6,7} necessitating more aggressive

medical or surgical glaucoma care over time.¹² Finally, a greater proportion of patients with XFG may get referred to glaucoma subspecialists to care for them, and these providers may be more aggressive at managing them medically and surgically relative to other eye care providers.

There has been a growing interest among health policymakers to look for alternatives to FFS Medicare to try to curtail rising healthcare costs. One alternative to reimbursing providers based on FFS that has been receiving a lot of attention is the creation of episodes of care. All healthcare services that constitute a given episode are lumped into a single bundled payment that is given to a healthcare provider to manage all aspects of care for the condition of interest over a set period of time. Examples of Centers for Medicare & Medicaid Services demonstration projects involving episodes of care include knee and hip replacement surgery.²¹ While we are unaware of any episodes of care that have been developed specifically for glaucoma, in the event that policymakers or insurers look to develop episodes of care or bundling of payments for this condition, it will be imperative for them to consider the type of glaucoma, and its severity and complexity, as well as the length of time one has the condition when determining the appropriate payment for such a bundle. Our findings that patients with newly diagnosed XFG cost, on average, approximately \$350 more per year to manage and that those with established disease cost, on average, more than \$500 more per year to manage highlights the importance of considering the type of glaucoma in such payment algorithms. If policymakers reimburse eye care providers the same amount of money to manage patients with XFG as they do for POAG, providers may be forced to have to skimp on care because of insufficient resources to manage these patients properly. Furthermore, some eye care providers may opt not to care for patients with XFG, knowing they may be unable to offer these patients the same quality of care as others with POAG. Given that patients with XFG tend to have higher IOP^{6,7,10} and wider fluctuations in IOP^{6,7} compared to persons with POAG, these patients need greater, not less, monitoring and surveillance to prevent disease progression and risk of blindness.

Our study has several limitations. First, we lacked data about the status of each enrollee's glaucoma prior to plan entry. Second, while we used a 3-year lookback period to try to properly categorize and distinguish those with incident disease from those with preexisting disease, it is possible that some patients with preexisting disease may have simply not sought eye care for the initial 3 years in the plan and thus, in the dataset, appear as incident cases. Prior work from our group has demonstrated that a 3-year lookback period is often sufficient to distinguish persons with incident from nonincident glaucoma.²² Third, some patients in each group may have been misdiagnosed or miscoded with the conditions of interest. To try to limit the potential for misdiagnosis, we restricted our study

sample to persons who were phakic, as it is often easier to distinguish XFG from POAG prior to cataract removal. In addition, to limit the potential for miscoding to affect our findings, we required a confirmatory diagnosis of the condition of interest on a separate date. In the event that some patients with XFG were misclassified as POAG or vice versa, this would bias our findings to the null. Fourth, claims data lack information about clinical variables of interest, such as the level of IOP, results from the diagnostic testing to adequately capture the complexity of each patient's disease, and details about the optic nerve or nerve fiber layer. Glaucoma severity at the time of incident diagnosis was coded for very few patients (only 7%), so unfortunately this could not be considered in our analyses.

Finally, since our study sample were enrollees in FFS Medicare, it is uncertain whether the findings generalize to patients with other types of health insurance, those who are uninsured, or those residing outside of the United States.

In conclusion, healthcare resource utilization and cost associated with caring for patients with XFG are significantly higher compared to others with POAG on almost every metric we evaluated. The findings from these analyses highlight the importance of considering the type of glaucoma, its severity, and the length of time with the condition when insurers and policymakers develop algorithms for alternative payment models to ensure patients are able to receive high-quality, cost-effective care.

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REFERENCES

1. Lee PP, Walt JG, Doyle JJ, et al. A multicenter, retrospective pilot study of resource use and costs associated with severity of disease in glaucoma. *Arch Ophthalmol* 2006;124(1):12–19.
2. Pasquale LR, Dolgitsier M, Wentzloff JN, et al. Health care charges for patients with ocular hypertension or primary open-angle glaucoma. *Ophthalmology* 2008;115(4):633–638.
3. Quigley HA, Cassard SD, Gower EW, Ramulu PY, Jampel HD, Friedman DS. The cost of glaucoma care provided to Medicare beneficiaries from 2002 to 2009. *Ophthalmology* 2013;120(11):2249–2257.
4. Stein JD, Ayyagari P, Sloan FA, Lee PP. Rates of glaucoma medication utilization among persons with primary open-angle glaucoma, 1992 to 2002. *Ophthalmology* 2008;115(8):1315–1319.
5. Stein JD, Niziol LM, Musch DM, et al. Longitudinal trends in resource use in an incident cohort of open-angle glaucoma patients. *Am J Ophthalmol* 2012;154(3):452–459.
6. Konstas AG, Hollo G, Astakhov YS, et al. Factors associated with long-term progression or stability in exfoliation glaucoma. *Arch Ophthalmol* 2004;122(1):29–33.
7. Konstas AG, Mylopoulos N, Karabatsas CH, et al. Diurnal intraocular pressure reduction with latanoprost 0.005% compared to timolol maleate 0.5% as monotherapy in subjects with exfoliation glaucoma. *Eye (Lond)* 2004;18(9):893–899.
8. Ritch R, Schlotzer-Schrehardt U. Exfoliation syndrome. *Surv Ophthalmol* 2001;45(4):265–315.
9. Ritch R, Schlotzer-Schrehardt U, Konstas AG. Why is glaucoma associated with exfoliation syndrome? *Prog Retin Eye Res* 2003;22(3):253–275.
10. Vesti E, Kivela T. Exfoliation syndrome and exfoliation glaucoma. *Prog Retin Eye Res* 2000;19(3):345–368.
11. Tornqvist G, Drolsum LK. Trabeculectomies. A long-term study. *Acta Ophthalmol (Copenh)* 1991;69(4):450–454.
12. Lim SH, Cha SC. Long-term outcomes of mitomycin-c trabeculectomy in exfoliative glaucoma versus primary open-angle glaucoma. *J Glaucoma* 2017;26(4):303–310.
13. American Medical Association. International Classification of Diseases, 9th Revision, Clinical Modification: ICD-9-CM. Salt Lake City, Utah: Medicode; 1996.
14. American Medical Association. CPT 2006. Chicago, Illinois: AMA Press; 2006.
15. Newman-Casey PA, Woodward MA, Niziol LM, Lee PP, De Lott LB. Brand medications and Medicare Part D: how eye care providers' prescribing patterns influence costs. *Ophthalmology* 2018;125(3):332–339.
16. Gross FJ, Tingey D, Epstein DL. Increased prevalence of occludable angles and angle-closure glaucoma in patients with pseudoexfoliation. *Am J Ophthalmol* 1994;117(3):333–336.
17. Hiller R, Sperduto RD, Krueger DE. Pseudoexfoliation, intraocular pressure and senile lens changes in a population-based survey. *Arch Ophthalmol* 1982;100(7):1080–1082.
18. Kanthan GL, Mitchell P, Burlutsky G, Rochtchina E, Wang JJ. Pseudoexfoliation syndrome and the long-term incidence of cataract and cataract surgery: the Blue Mountains Eye Study. *Am J Ophthalmol* 2013;155(1):83–88.

19. Desai MA, Lee RK. The medical and surgical management of pseudoexfoliation glaucoma. *Int Ophthalmol Clin* 2008;48(4): 95–113.
20. Lee PP, Kelly SP, Mills RP, et al. Glaucoma in the United States and Europe: predicting costs and surgical rates based upon stage of disease. *J Glaucoma* 2007;16(5):471–478.
21. Centers for Medicare & Medicaid Services. Comprehensive Care for Joint Replacement Model. Available at: 2018. <https://innovation.cms.gov/initiatives/cjr>. Accessed March 3, 2018.
22. Stein JD, Blachley TS, Musch DC. Identification of persons with incident ocular diseases using health care claims databases. *Am J Ophthalmol* 2013;156(6):1169–1175.