Total and Disease Specific Resource Use and Healthcare Cost of Patients with Glaucoma

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Abstract

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Introduction

Glaucoma is an irreversible, progressive, optic neuropathy. Left unmanaged, glaucoma can lead to blindness. Open angle glaucoma is the most common type, and primary (idiopathic) open angle glaucoma (POAG) is the most common sub-type. POAG was estimated to affect almost 3 million Americans in 2010. Surgical and medical interventions can be employed to manage the progression of disease and help prevent blindness. Previous literature has estimated the utilization and financial burden of disease, with a few studies also reporting outcomes as vision loss worsens, but few have included drug claims. The primary objective of this study was to characterize the overall and disease-related healthcare resource use,

including drug utilization, and cost associated with treatment and care provided to glaucoma patients.

Methods

A retrospective analysis of a US commercial claims database was performed. Patients were stratified into vision loss categories of no vision loss, mild, moderate, or severe vision loss and blindness using two different classification systems. Outcomes of interest were frequency and mean cost of specific service categories, unadjusted and adjusted mean annual total healthcare cost and unadjusted and adjusted mean annual cost of glaucoma specific care. Outcomes were reported over one year following the diagnosis of glaucoma.

Results

Few patients were identified as having vision loss, as determined by the two classification schemes employed (Javitt or ICD-9). In general, the frequency of total healthcare and glaucoma specific services increased from the pre-index period to the post-index period. The magnitude of increase was higher for vision related services. Overall, the unadjusted mean total healthcare cost per patient and unadjusted mean glaucoma specific cost per patient increased from pre-index to post-index period for all vision loss categories. There was no trend observed for unadjusted mean total healthcare cost or unadjusted mean glaucoma specific cost as vision loss progressed. Adjusted cost ratios for total healthcare cost and glaucoma specific cost did not result in a trend as vision loss progressed.

Conclusion

We characterized total healthcare and glaucoma specific utilization and cost for patients during the 12 months prior to and 12 months following their glaucoma diagnosis. We found that utilization and cost of services increased from the pre-index period to the post-index period. But, we were unable to detect a trend in adjusted total healthcare and adjusted

glaucoma specific cost as vision loss progressed. Future work to increase the cohort size, specifically to include older patients, may improve our ability to detect a trend as vision loss progresses.

INTRODUCTION

Glaucoma is defined as an irreversible, progressive, optic neuropathy. It is the second leading cause of legal blindness worldwide and in the United States.[1] Glaucoma can broadly be classified as congenital, angle-closure, or open-angle (OAG). OAG is the most common classification of glaucoma. Glaucoma can further be classified as either primary—idiopathic, no known explanations of disease; or secondary—associated with detectable comorbidity such as pigment dispersion, pseudoexfoliation, uveitis, trauma, or corticosteroid use. Primary open angle glaucoma (POAG) is more common in the population than secondary open angle glaucoma. POAG prevalence is higher among people of African and Latino descent compared to those of Non-Hispanic White descent.[2,3] In 2010, POAG was estimated to affect 2.8 million people over the age of 40 in the US, this is to projected increase to 3.36 million by 2020.[4,5,6]

The exact etiology of POAG is not fully understood. Disease progression is marked by retinal ganglion cell loss and nerve damage that leads to deterioration of central field vision. Primary open-angle glaucoma generally presents without symptoms, but can often be associated with increased intraocular pressure (IOP) (although, this is not a requirement for diagnosis). It has been estimated that approximately one-sixth of POAG patients will consistently have an (IOP) in the normal range.[7] Several studies provide evidence that IOP plays an important role in the neuropathy of POAG. These have also demonstrated that if IOP is increased, reducing IOP is associated with a decrease in risk of central visual field loss and progression of the disease.[8,9,10,11,12] Surgical and medical interventions can be employed to decrease IOP. Studies support the efficacy of surgical interventions to reduce IOP to a greater degree than medical management.[13,14,15,16] The most common surgery is laser trabeculoplasty and trabeculectomy (filtering surgery). Several therapeutic classes of topical eye drops are used in medical management, including prostaglandin analogs, beta-

adrenergic antagonists, alpha-adrenergic antagonists, parasympathomimetic agents, and carbonic anhydrase inhibitors; these may be used to help maintain or lower IOP.

Regular evaluation of disease progression, and treatment when necessary, is important in a chronic disease that can lead to blindness. A 2003 article reported that approximately 120,000 Americans were blind due to glaucoma, resulting in an estimated cost of 1.5 billion dollars in benefits, lost tax revenues, and health expenses.[1,6] Since this estimate, other studies have aimed to determine costs associated with glaucoma care aside from the outcome of blindness. Of note, a 2008 article used Medicare data to determine the costs associated with glaucoma care, stratified by vision loss severity category. In addition to the mean annual cost post-diagnosis, they also assessed clinical outcomes such as depression and falls.[17] Drug costs were not included since the data were collected prior to the initiation of Medicare Part D. A more recently published study used Medicare data from 2002 to 2009 to determine the inpatient and outpatient costs of treatment for glaucoma (open and closed angle) patients, separated by service type—such as office visit, diagnostic test, or surgery. As in the previous study, these investigators did not analyze drug utilization or costs.[18] Unlike the previous study, they did not incorporate outcomes resulting from vision loss, nor did they stratify the population by vision loss severity categories.

These articles provide valuable information about healthcare utilization and the cost of patients with glaucoma. But, questions remain unanswered about the costs incurred from medication use, and populations other than Medicare beneficiaries. To address this gap in literature, the aim of this study is to characterize the overall and disease-related healthcare resource use, including drug utilization, and cost associated with glaucoma patients through a retrospective analysis of a US commercial claims database.

Methods

Data Source

Data for this analysis were acquired from the Truven Health MarketScan® 2009 to 2012 Commercial Claims and Encounters databases. MarketScan is a large, nationally representative, proprietary database that encompasses over 170 million unique patients since its creation in 1995. There were over 56 million insured lives included in the 2011 annual database. MarketScan annual summary enrollment file was used to obtain baseline cohort demographics and characteristics. Inpatient admissions (a summary file), inpatient and outpatient service files (claim specific), and an outpatient drug claims file were used for the analysis. All claims included have been paid and adjudicated since data are not collected for the annual database until nearly 100 percent of claims have been paid. Each person in the database has a unique enrollee identifier, which is created through encrypting information provided by the data contributors. The MarketScan database is fully HIPAA compliant and is considered a limited-use dataset by HIPAA definition.[19]

Cohort Identification

Two occurrences of ICD-9 glaucoma diagnoses were required for inclusion into the cohort. In particular, ICD-9 codes of 365.10, "open-angle glaucoma, unspecified" or 365.11, "primary open-angle glaucoma" were used. Any combination of these two ICD-9 codes were required to have occurred within 365 days of each other, on separate days. The date of the first occurrence of glaucoma diagnosis was considered to be the index date with the second date of glaucoma diagnosis serving as confirmation of disease. The index date was identified in either the 2011 inpatient or 2011 outpatient claims files and was the date from which pre-index (baseline) and post-index (follow-up) utilization and cost were determined. Patients were excluded if they were under the age of 18, had a claim with an ICD-9 code

that may indicate other causes of blindness (Appendix A), or who had incomplete claims information in the 12 months prior to or following the index date.

Vision Loss Stratification

Two methods of vision loss stratification were used in this analysis. To maintain comparability with the 2008 Bramley article, the first method of stratification was a classification system outlined by Javitt, et al. This classification system is not glaucoma specific, but was created for use in diseases that cause blindness. It uses 57 different vision loss ICD-9 codes to classify patients into categories of moderate vision loss, severe vision loss, and blindness.[20] The second method of stratification utilizes the 2011 implemented glaucoma add-on ICD-9 codes of 365.71-73. Unlike the Javitt classification system, these codes are specific to glaucoma and indicate mild, moderate, or severe forms of the disease, based on vision loss in the worse eye.[21]

A pre-index and a post-index vision loss classification were determined for both the Javitt and ICD-9 vision loss severity schemes described. ICD-9 codes associated with claims that occurred on the index date or in the 365 days preceding it were eligible for classifying pre-index vision loss. And claims in the 365 days after the index date were eligible for classifying post-index vision loss. In the case of multiple claims with ICD-9 codes matching those in the classification schemes, the ICD-9 code/claim closest to the index date was used for the pre-index classification and the ICD-9 code/claim farthest from the index date was used for the post-index vision loss classification. Pre-index vision loss stratification was used for the analysis portion of this study.

Assessment of Total Healthcare, Glaucoma Specific, and Drug Utilization and Costs

Service categories related to patient care were chosen to assess overall healthcare and drug utilization. These included: inpatient stays, emergency department (ED) claims, general

office visits, vision related office visits, glaucoma diagnostic tests, glaucoma surgeries, and medication fills (new prescriptions or refills). Pre-index frequency of utilization and cost were determined by identifying claims that occurred in the 365 days prior to the index date. Post-index frequency of utilization and cost were determined by identifying claims that occurred on the index date or in the 365 days following it.

An inpatient summary file that compiles claims associated with an overnight hospital stay was used to determine the frequency and number of patients who had an inpatient stay during the pre- and post- index periods. Current procedural terminology (CPT) codes were used to identify claims in either inpatient or outpatient files that were associated with the service categories of interest (Appendix B). The frequency of medication fills (new or refill) was determined using the drug file. The overall frequency of each service category was reported along with the number of patients contributing to the frequency.

The same service categories were used to determine glaucoma specific utilization. An added requirement to be classified as "glaucoma specific," was the presence of a glaucoma diagnosis (ICD-9: 365.10, 365.11, or 35.71-73) attached to the service category claim. National Drug Codes (NDC) associated with medications for the treatment of glaucoma were used to identify drug claims that would be classified as "glaucoma specific." The frequency of these claims was reported for the pre and post index period along with the number of patients contributing to the frequency.

The costs reported reflect the payment received by the provider. This is the same cost that the plan is responsible for after the patient deductible, coinsurance and coordination of benefits are considered. Unadjusted mean costs with 95% confidence intervals are reported for the service categories of interest. Total healthcare cost is the sum of costs associated with all inpatient, outpatient and drug claims. Glaucoma specific costs are the sum of inpatient and outpatient claims associated with any claim deemed to be "glaucoma specific,"

as outlined above, as well as drug claims for medications used in the treatment of glaucoma. Both total healthcare and glaucoma specific costs were reported for the pre-index and post-index periods.

Baseline Comorbidity

To address potential differences in baseline comorbidity that could affect healthcare utilization and cost during the follow up period, the Deyo-Charlson Comorbidity Index Score was calculated for each patient using 365 days of inpatient and outpatient claims data prior to their index date. This score utilizes weights for different comorbidities (liver disease, diabetes, AIDS, cancer, etc.) to create a summary indicator of baseline health status.[22] Comorbidity weights are added together to create a score, and a higher score indicates more baseline risk.

Statistical Analyses

To understand the data as a whole, as well as the differences between glaucoma stratification categories, univariate analyses and descriptive statistics were performed to obtain means, medians, and 95% confidence intervals of continuous variables, and counts with proportions for categorical variables. The frequency of improvement or worsening of vision loss over the pre- and post-index period was calculated since vision loss categorization was determined through pre-index and post-index claims information.

Cost data historically has a non-normal distribution, with a long, heavy right-tail (right-skewness).[23] To overcome this violation of a linear regression assumption, cost data are often log-transformed to approximate a normal distribution prior to performing regression analysis. After retransforming the data into the original scale, issues in estimation and interpretation exist due to log costs resulting in geometric means rather than arithmetic means. An alternative method to log transformation prior to linear regression is to use a

generalized linear model (GLM). GLM is more flexible than a linear model and does not require normality or homoscedasticity of the data. There is no transformation of data prior to regression and so there is no issue of interpreting cost differences, since estimation occurs on the same scale. In a GLM, a "link" function and "family" must be specified. The "link" function characterizes how the dependent variable and linear combination of independent variables are related. The "family" specified refers to the distribution that reflects the mean-variance of the dependent variable. Specifying a gamma family reflects variance that is proportional to the square of the mean and a Gaussian family reflects constant variance. A GLM that uses Gaussian family and identity link would be equivalent to performing an ordinary least squares regression, while a GLM that specifies a Gaussian family and log link would be equivalent to log-transforming the dependent variable prior to linear regression. Use of a GLM with log link and gamma family is common in cost analysis since it considers both the non-normal distribution and heteroscedasticity of cost data. After a GLM is performed, cost ratios and incremental costs can be determined comparing a vision loss category to the reference group of no vision loss.

The unadjusted model consisted of one-year follow up cost (total and glaucoma specific) as the outcome of interest and vision loss category as the predictor of interest. To improve model fit, all baseline characteristics were considered as covariates. Patient characteristics were chosen as model covariates based on adjusted models found in other recent literature[17] and scientific reasoning (variables were not included or excluded based on statistical significance). Covariates chosen for inclusion were: age (as a continuous variable and as a categorical variable), sex, baseline Charlson comorbidity score, pre-index/baseline costs, geographic region, and presence of pre-index ocular hypertension. Cost ratios comparing vision loss categories to the reference category of no vision loss were obtained from unadjusted and adjusted GLM using gamma family and log link for total healthcare and glaucoma specific costs. Marginal costs were also obtained by performing the "margins"

command in STATA that calculates the incremental cost of groups within a categorical variable. The multivariable analyses were completed using robust standard errors and a significance level of α= 0.05. All statistical analyses were completed using STATA 13-IC for moderate sized datasets (StataCorp LP, College Station, TX).

Results

Study population

A total of 418,572 persons were identified as having one glaucoma claim in the years 2010 though 2011. There were 133,137 patients identified as having glaucoma by the inclusion definition of two qualifying glaucoma diagnosis codes. As shown in Figure 1, approximately 500 patients were excluded for age less than 18 years old; 60,000 patients were excluded due to presence of other possible causes of glaucoma or blindness and another 55,000 were excluded due to incomplete claims information. 8,575 patients remained after excluding those with index dates outside of 2011.

Approximately half of the cohort was female (n=4,372; 51%), in the age range of 55 to 64 years old (n=4,825; 56%), and had a Charlson comorbidity score of 0 (n=5,049; 59%). [Table 1] The majority of the cohort was insured under a preferred provider organization (PPO) (n=5,660; 66%); health maintenance organization (HMO) was the second most common insurance type (n=923; 11%). The South was the region with the largest number of patients (n=3,683; 43%) and the Northeast and West regions had the lowest number of patients (n=1,092; 13% and n=1,274; 15%, respectively). 651 (8%) members of the cohort had a diagnosis of ocular hypertension in the pre-index period.

Vision loss classification

Using pre-index claims, the Javitt vision loss severity classification and the add-on ICD-9 diagnosis coding classification scheme showed that the cohort generally had no vision loss

(n=8557, >99%; n=8411, 98% respectively). In fact, the Javitt classification scheme only identified 18 persons who had any vision loss and the ICD-9 classification scheme identified a total of 164 persons with any vision loss. [Table 2]

The number of patients identified as having any vision loss did not increase using the Javitt classification and post-index claims, but the proportion of patients in each vision loss category shifted. 30 patients shifted vision loss categories resulting in 2 more persons in the moderate category, 3 less persons in the severe category, and 1 person in the blind category. The number of subjects identified with vision loss using the ICD-9 classification system increased five fold to 899 when using post-index claims compared to pre-index. 813 patients shifted vision loss categories resulting in an increase of 434 patients in the mild vision loss group, 222 patients in the moderate vision loss group and 79 patients in the severe vision loss group. Frequencies and percentages are reported in Table 3.

Total healthcare utilization

The frequency of claims identified through both inpatient and outpatient claims files increased from the pre-index to post-index period for all healthcare service categories, with the exception of outpatient visits identified through the inpatient claims file. [Table 4.1] In this category, the pre-index period had 5 claims, while the post-index period only had 4 claims. Of note, the frequency of vision related service categories increased a minimum of two fold from the pre-index to the post-index period. [Table 4.2]

Total healthcare cost

Inpatient stays was the service category with the highest unadjusted mean cost in the pre-index period at approximately $21,000 per patient (PP); this increased to about $25,000 PP in the post-index period. The unadjusted mean total healthcare cost in the pre-index period was $5,405 PP and this increased to $7,106 PP in the post-index period. [Tables 5, 6] The

distribution of the unadjusted mean pre-index and post-index total healthcare cost can be seen in Figures 2 and 3. Using the Javitt classification system, the unadjusted mean total healthcare cost per patient increased from the pre-index to post-index period for all vision loss categories. Pre-index mean total healthcare cost did not increase as vision loss worsened; no vision loss: $5,405 PP, moderate vision loss: $6,287 PP, severe vision loss: $3,281 PP. Similarly, the unadjusted post-index mean total healthcare cost per patient did not produce a linear trend; no vision loss: $7,106 PP, moderate vision loss: $7,146 PP, and severe vision loss: $6,834 PP. The ICD-9 classification scheme produced mean total healthcare cost trends in agreement with the Javitt classification [Table 6]: mean total healthcare cost increased from pre-index to post-index periods for all vision loss categories; but, when looking at pre-index and post-index unadjusted mean total healthcare cost per patient separately, there was no linear trend detected as vision loss progressed.

Using the Javitt vision loss categories, the multivariable adjusted GLM regression analysis predicted mean total healthcare cost for those with moderate vision loss was 19% less than those with no vision loss. [Table 7] Those with severe vision loss had an increase in mean total healthcare cost of 80% over no vision loss. When looking at ICD-9 vision categories, predicted adjusted total healthcare cost decreased by 36% for those with mild vision loss and by 42% for those with moderate vision loss compared to no vision loss. Predicted adjusted total healthcare costs increased by 24% for those with ICD-9 categorized severe vision loss compared to no vision loss, findings are summarized in Table 7.

Since the number of persons in each vision loss category was very small in relation to the total number, comparisons of no vision loss to any vision loss were also completed and reported. [Table 9] The calculated unadjusted and adjusted total healthcare incremental costs vary, with no linear pattern, as vision loss progresses for both vision loss classification schemes. For the Javitt classification system, costs decreased by $1,307 for moderate vision loss and increased by $5,410 for severe vision loss when comparing to no vision loss. When

comparing the vision loss categories to no vision loss using the ICD-9 classification system, the marginal cost ranged from a decrease of $2,875 to an increase of $1,661.

Glaucoma specific healthcare utilization

As with the total healthcare utilization, the frequency of all glaucoma specific service categories increased from the pre-index period to the post-index period. The increase in frequency was variable for the different service categories, but the magnitude of increase was much higher than what was observed in the total healthcare utilization. [Table 4.3]

Glaucoma specific healthcare cost

In general, the unadjusted mean cost per patient for glaucoma specific service categories increased from the pre-index period to the post-index period for all vision loss categories, including the any vision loss category. For the overall cohort, the unadjusted mean total glaucoma specific cost per patient was $107 for the pre-index period, which increased to $487 in the post-index period. [Table 5, 6] The distribution of unadjusted mean glaucoma specific costs can be seen in Figures 2 and 3. Using the Javitt or ICD-9 classification of any vision loss, the unadjusted mean glaucoma specific cost increased from the no vision loss category. And, similar to total healthcare costs, there was no linear pattern detected in unadjusted mean glaucoma specific cost as vision loss progressed from no vision loss to severe vision loss for either the Javitt [Table 5] or ICD-9 [Table 6] classification schemes.

Using GLM regression, the adjusted post-index glaucoma specific mean cost increased from no vision loss by 30% for those classified as having any vision loss by the Javitt classification and by 8% for those classified as having any vision loss by the ICD-9 classification system. Cost ratios for specific vision loss categories using the two classification systems can be found in Table 8. Derived from the same models as the cost ratios, the unadjusted and adjusted glaucoma specific incremental costs can be found in

Table 10. There was no pattern observed in the unadjusted or adjusted glaucoma specific incremental costs as vision loss progressed.

Discussion

This study characterized the frequency and mean cost of services for categories including: inpatient stays, ED claims, office visits, vision related office visits, glaucoma diagnostic tests, glaucoma surgeries and medication fills. The results suggest that for all service categories, utilization increased from the pre-index period to the post-index period, after combining services found through inpatient and outpatient claims files. The same trend was seen in the glaucoma specific services, but to a much higher magnitude—a three to 50 fold increase was seen when comparing post-index to pre-index frequencies. In general, the trend also held when comparing pre- and post-index mean costs of total healthcare and glaucoma specific services. Unadjusted and adjusted models estimated cost ratios and incremental costs for total healthcare and glaucoma specific categories. Adjusted models using Javitt and ICD-9 categorized any vision loss compared to no vision loss did not produce congruent cost ratios for total healthcare cost, but adjusted cost ratios were in agreement for glaucoma specific cost.

We were not able to identify an increase in trend for frequency of services as vision loss progressed using the Javitt or ICD-9 vision loss categorization schemes. We were also unable to identify a clear trend in post-index total healthcare costs or total glaucoma specific costs as vision loss progressed using either classification schemes. This is likely due to the low number of patients we identified as having any vision loss using either classification scheme. The mean post-index total healthcare cost hovered around $7,000 for all Javitt vision loss categories, and, using ICD-9 classification, varied from approximately $7,000 for no vision loss to $6,000 for mild vision loss and $4,000 for moderate and severe vision loss.

These adjusted mean total healthcare costs for increasing vision loss are lower than what has been previously published. Javitt and Bramley both found clear trends of increase in total healthcare cost as vision loss severity increased from no vision loss to blindness. Javitt reported the range of mean cost for non-eye related care to increase from $5,954 to $7,527 for no vision loss up to $14,444 to $19,366 for those with blindness.[20] Bramley found mean total healthcare costs to be $8,157 for no vision loss increasing to $18,670 for those with blindness.[17] The mean total healthcare cost, for any vision loss group, determined through this study would fall into the range of no vision loss when compared to results from the Javitt and Bramley articles.

Some methodological and population differences between our work and the studies under discussion may explain some of the discrepancies in cost seen. Javitt looked at patients with and without glaucoma, removed eye-care costs, reported 2003 non-eye care payments (not costs), and used a Medicare sample (all patients were over 65 years old), with a four year follow up period. Bramley looked solely at patients with glaucoma, and reported total healthcare costs with one-year follow up, similar to the current study. They used a Medicare sample creating a population with a mean age of 74 years old, which was 63% female and had a mean Charlson co-morbidity score of 1.26. Neither study used drug costs as part of their total healthcare cost. The differences in age and Charlson score likely indicate a higher risk population that may incur increased costs of care. This, in addition to the low number of patients with any vision loss in this study may explain why an increase in trend was not observed.

Like the post-index total healthcare costs, the post-index glaucoma specific costs varied over vision loss categories for the Javitt vision loss categorization. The mean post-index glaucoma specific cost increased from no vision loss to moderate vision loss, and then decreased for those with severe vision loss. By ICD-9 vision loss categorization, mean post-index glaucoma specific cost was about the same for both non-vision loss and mild vision

loss categories (~$500), and slightly increased to be about the same for both those with moderate and severe vision loss (~$600). The post-index glaucoma specific mean costs determined through this study were somewhat similar to findings by previous studies completed by Quigley et al[18], and Lee et al[24]. Again, there are differences in methodology that prevent direct comparisons.

Quigley[24] used Medicare data; so all patients were over the age of 65. Quigley determined a 2009 mean glaucoma cost of $263 for those with OAG and $228 for those with any type of glaucoma. They used payments instead of costs and did not look at cases of newly diagnosed glaucoma. Lee, et al.[24] used data from 1998 to 2004 from a commercial claims database (not MarketScan) to determine that eye related costs were $623 for those with ocular hypertension or low risk of progressing, and this increased to $2,511 for those who were blind. Lee included a large proportion of patients under the age of 65 years old (66%), about half were female (55.7%) and they included pharmacy claims, similar to our methods and results. But, the reported costs were based on Medicare charges and the mean Charlson comorbidity score was 3.5, which was much higher than the mean Charlson score of the current cohort. The lower baseline risk and use of Medicare charges could explain why, despite having similar methods to the Lee study, the post-index mean glaucoma specific cost was less than results in the Lee study.

Cost ratios and marginal costs obtained through a multivariate generalized linear model do not express an increased trend as vision loss progresses. These results are incongruous with the findings of the Javitt study that used linear regression. After Javitt adjusted for age groups, gender, race, diabetes, and vision loss categories, they determined an adjusted excess cost over their study period as vision loss increased. If a patient had no vision loss at the beginning of the study, and remained with no vision loss, their adjusted cost increased by $5,225; for progression to moderate vision loss, the cost increased by $7,576; for progression to severe vision loss, the cost increased by $9,973; and for progression to

blindness, the cost increased by $11,621. Bramley also completed a multivariable linear regression but did not report any incremental cost differences for vision loss categories calculated from it.

Several possible explanations exist as to why the cost ratios and marginal costs did not produce a trend as expected. Lack of patients identified in vision loss categories may prevent good model fit and the ability to accurately predict the post-index total and glaucoma specific cost. Outliers in the vision loss categories with low numbers of patients may greatly bias mean outcomes as well. To explore model fit, a Poisson family and a power link were substituted into the proposed GLM regression with gamma family and log link (results not shown). The results were aligned with those obtained using the proposed GLM regression. In addition to providing similar results, the gamma family and log link provide results that are easier to interpret and understand.

The findings for mean costs and adjusted costs as vision loss progressed were not what was expected when compared to results from other studies. As mentioned previously, this may be due to very few patients identified as having any vision loss. Along with this, the cohort identified was generally younger with less baseline risk (Charlson comorbidity score) compared to other studies. This is most likely due to the fact that we used an administrative commercial claims database that does not cover many patients after they turn 65 and are eligible for Medicare.

Several other limitations exist when completing a claims database analysis. Potential errors in coding a claim can occur and this can introduce bias, or misclassify patients in the cohort or, while unlikely, misclassify service claims if they were coded using the incorrect date of service. A claims database also fails to capture services not adjudicated through insurance. We tend to think this mainly affects drug claims that are paid as cash, but some surgeries may also fall in this category. This would underestimate our mean costs, and affect the

adjusted costs. Lastly, use of a claims database infers that the population examined is of a certain socioeconomic standing. We assume that the patient, or a relative, is healthy enough to work and provide insurance in the first place. This introduces healthy worker bias that may result in lower mean and adjusted costs than would otherwise be determined.

This study's strengths include being the first study, of which we are aware, to use generalized linear modeling to estimate adjusted marginal costs comparing vision loss categories to no vision loss. This model type is gaining popularity over ordinary linear regression with log cost transformation because of its ease of interpretation and les biased results since retransformation is not needed. We also categorized vision loss using two different classification schemes to increase comparability to published studies. Use of the MarketScan database allowed us to have great detail in the claims information and investigate a younger population affected by glaucoma, since most literature in this area reports on patients older than 65 years of age. By using a US commercial claims database, this work also brings a different perspective to the current body of literature on glaucoma costs.

Future work that may provide interesting results would be to increase the length of time in the index period, which may increase cohort size and identify more patients with vision loss. The study methods used could also be applied to a different database or even a Medicare sample to see if results are more aligned with previous literature. And lastly, further investigation into different model selections may yield a better fit for the data; bootstrapping methods could also be used to better estimate variance of adjusted costs.

Conclusions

The results of this study estimate total and glaucoma specific unadjusted and adjusted mean costs of inpatient stays, office visits, ED claims, vision related office visits, glaucoma diagnostic tests, glaucoma surgeries, and drugs for patients with newly diagnosed glaucoma in a commercial claims database. In general, frequency of these services increased after glaucoma diagnosis, with a higher magnitude observed for vision related services. GLM regression adjusted total healthcare and glaucoma specific post-index costs did not increase as vision loss progressed, when categorized by Javitt and ICD-9 classification schemes.

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Figure 1. Cohort selection

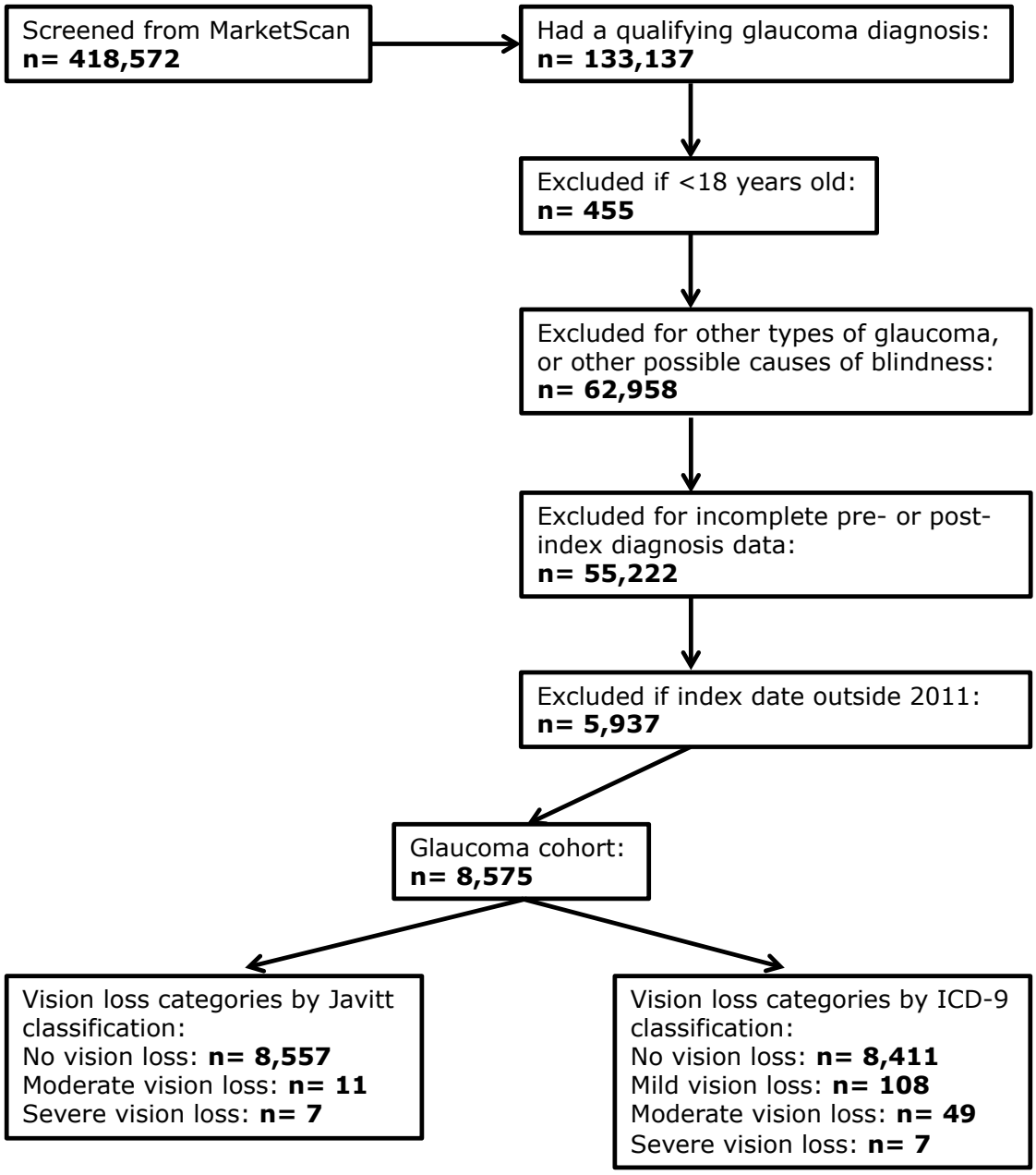

Table 1. Baseline demographics using pre-index vision loss categorization.

		JAVITT VISION LOSS CATEGORIES			ICD-9 VISION LOSS CATEGORIES			
Characteristic	**Overall cohort**	**None**	**Moderate**	**Severe**	**No vision loss**	**Mild: 365.72**	**Moderate: 365.72**	**Severe: 365.73**
N	8,575	8,557	11	7	8,411	108	49	7
(% of N)	100.0%	99.8%	0.1%	0.1%	98.1%	1.2%	0.6%	0.1%
Mean age (yrs)	53.9	53.9	52.7	52.1	53.8	53.7	54.2	49
(95% CI)	(53.7, 54.1)	(53.7, 54.0)	(45.6, 59.9)	(44.0, 60.3)	(53.7, 54.1)	(52.3, 55.2)	(51.9, 56.4)	(35.9, 62.1)
age range (yrs)	18 - 64	18 - 64	29 - 63	40 - 63	18 - 64	32 - 64	36 - 64	20 - 62
18 to 34 age group (n)	276	275	1	0	269	6	0	1
35 to 44 age group (n)	748	744	2	2	735	5	7	1
45 to 54 age group (n)	2,726	2,722	3	1	2,677	34	13	2
55 to 64 age group (n)	4,825	4,816	5	4	4,730	63	29	3
Female (n)	4,372	4,367	3	2	4,284	59	25	4
[% of vision loss category]	51%	51%	27%	29%	51%	55%	51%	57%
Mean Charlson Score	0.89	0.89	1.18	0.86	0.88	1.17	1.41	1.43
(95% CI)	(0.86, 0.92)	(0.86, 0.92)	(-0.01, 2.38)	(-0.27, 1.98)	(0.85, 0.91)	(0.81, 1.52)	(0.85, 1.97)	(0.30, 2.83)
Charlson score 0 (n)	5,049	5,039	6	4	4,961	61	24	3
[% of vision loss category]	59%	59%	55%	58%	59%	56%	49%	43%
Charlson score= 1 (n)	1,422	1,419	2	1	1,403	13	6	0
[% of vision loss category]	16%	17%	18%	14%	17%	12%	12%	0%
Charlson score= 2 (n)	1,051	1,049	1	1	1,025	15	8	3
[% of vision loss category]	12%	12%	9%	14%	12%	14%	16%	43%
Charlson score >3 (n)	1,053	1,050	2	1	1,022	19	11	1
[% of vision loss category]	11%	12%	18%	14%	12%	18%	23%	14%
Pre-index ocular HTN (n)	651	650	1	0	637	11	3	0
[% of vision loss category]	8%	8%	9%	0%	8%	10%	6%	0%
Region								
Northeast (n)	1,092	1,090	1	1	1,083	4	5	0
[% of vision loss category]	13%	13%	9%	14%	13%	4%	10%	0%
North Central (n)	2,229	2,226	2	1	2,173	43	11	2
[% of vision loss category]	26%	26%	18%	14%	26%	40%	22%	29%
South (n)	3,683	3,676	3	4	3,618	43	19	4
[% of vision loss category]	43%	43%	27%	57%	43%	40%	39%	57%
West (n)	1,274	1,270	3	1	1,251	12	11	0
[% of vision loss category]	15%	15%	27%	14%	15%	11%	22%	0%
Unknown (n)	297	295	2	0	287	6	3	1
[% of vision loss category]	3%	3%	18%	0%	3%	6%	6%	14%

Table 1 continued. Baseline demographics using pre-index vision loss categorization.

		JAVITT VISION LOSS CATEGORIES			ICD-9 VISION LOSS CATEGORIES			
Characteristic	**Overall cohort**	**None**	**Moderate**	**Severe**	**No vision loss**	**Mild: 365.72**	**Moderate: 365.72**	**Severe: 365.73**
N	8,575	8,557	11	7	8,411	108	49	7
(% of N)	100.0%	99.8%	0.1%	0.1%	98.1%	1.2%	0.6%	0.1%
Plan type^								
Comprehensive	337	337	0	0	335	2	0	0
EPO	202	202	0	0	200	1	1	0
HMO	923	922	1	0	910	6	6	1
Non-capitated POS	682	681	0	1	676	3	3	0
PPO	5660	5645	9	6	5538	81	35	6
POS with capitation	47	47	0	0	47	0	0	0
CDHP	420	420	0	0	409	8	3	0
HDHP	200	200	0	0	195	4	1	0
missing	104	103	1	0	101	3	0	0
Employment status*								
Active full time (n)	3,524	3,518	4	2	3,495	20	7	2
[% of vision loss category]	41%	41%	36%	29%	42%	19%	14%	29%
Active part time/seasonal (n)	67	67	0	0	66	0	0	0
[% of vision loss category]	1%	1%	0%	0%	1%	0%	2%	0%
Early retiree (n)	1,101	1,098	3	0	1,095	4	2	0
[% of vision loss category]	13%	13%	27%	0%	13%	4%	4%	0%
Medicare eligible retiree (n)	104	104	0	0	104	0	0	0
[% of vision loss category]	1%	1%	0%	0%	1%	0%	0%	0%
Retiree (status unknown) (n)	115	115	0	0	112	1	2	0
[% of vision loss category]	1%	1%	0%	0%	1%	1%	4%	0%
COBRA continuee (n)	17	17	0	0	17	0	0	0
[% of vision loss category]	< 1%	< 1%	0%	0%	< 1%	0%	0%	0%
Long term disability (n)	15	15	0	0	15	0	0	0
[% of vision loss category]	< 1%	< 1%	0%	0%	< 1%	0%	0%	0%
Surviving spouse/dependent (n)	32	32	0	0	32	0	0	0
[% of vision loss category]	< 1%	< 1%	0%	0%	< 1%	0%	0%	0%
Other/unknown (n)	3,600	3,591	4	5	3,475	83	37	5
[% of vision loss category]	42%	42%	36%	71%	41%	77%	76%	71%

^ plan type acronyms: Exclusive provider organization (EPO); Health maintenance organization (HMO); Point of service (POS); Preferred provider organization (PPO); Consumer driven health plan (CDHP); High deductible health plan (HDHP)

* Employment status of primary insurance holder

Table 2. Baseline demographics using post-index vision loss categorization.

		JAVITT VISION LOSS CATEGORIES				ICD-9 VISION LOSS CATEGORIES			
Characteristic	**Overall cohort**	**None**	**Moderate**	**Severe**	**Blind**	**No vision loss**	**Mild: 365.72**	**Moderate: 365.72**	**Severe: 365.73**
N	8,575	8,557	13	4	1	7,676	542	271	86
(% of N)	100.0%	99.8%	0.1%	0.1%	<0.1%	89.5%	6.3%	3.2%	1.0%
Mean age (yrs)	53.9	53.9	49.2	49.8	40	53.9	54.5	54.3	53.8
(95% CI)	(53.7, 54.1)	(53.7, 54.1)	(41.4, 57.0)	(31.5, 68.0)	40	(53.6, 54.0)	(53.9, 55.1)	(53.3, 55.3)	(52.4, 55.3)
age range (yrs)	18 - 64	18-64	18-62	36-63	40	18-64	19-64	19-64	24-64
18 to 34 age group (n)	276	274	2	0	0	258	9	8	1
35 to 44 age group (n)	748	744	2	1	1	673	48	21	6
45 to 54 age group (n)	2,726	2,721	3	2	0	2,431	176	83	36
55 to 64 age group (n)	4,825	4,818	6	1	0	4,314	309	159	43
Female (n)	4,372	4,363	7	1	1	3,899	300	132	41
[% of vision loss category]	51%	50%	54%	25%	100%	51%	55%	49%	49%
Mean Charlson Score	0.89	0.89	1.62	1.25	N/A	0.88	0.98	1.09	0.88
(95% CI)	(0.86, 0.92)	(0.86, 0.92)	(0.44, 2.8)	(-2.73, 5.23)	N/A	(0.85, 0.91)	(0.86, 1.10)	(0.88, 1.30)	(0.59, 1.17)
Charlson score 0 (n)	5,049	5,039	6	3	1	4,537	302	157	53
[% of vision loss category]	59%	59%	46%	75%	100%	59%	56%	58%	61%
Charlson score= 1 (n)	1,422	1,420	2	0	0	1,293	85	35	9
[% of vision loss category]	16%	17%	15%	0%	0%	17%	16%	13%	11%
Charlson score= 2 (n)	1,051	1,050	1	0	0	922	77	39	13
[% of vision loss category]	12%	12%	8%	0%	0%	12%	14%	14%	15%
Charlson score >3 (n)	1,053	1,048	4	1	0	924	78	40	11
[% of vision loss category]	11%	12%	31%	25%	0%	12%	14%	15%	13%
Pre-index ocular HTN (n)	651	650	1	0	0	580	51	18	2
[% of vision loss category]	8%	8%	8%	0%	0%	8%	9%	7%	2%
Region									
Northeast (n)	1,092	1,086	6	0	0	1,002	52	32	6
[% of vision loss category]	13%	13%	46%	0%	0%	13%	10%	12%	7%
North Central (n)	2,229	2,223	5	1	0	1,947	188	68	26
[% of vision loss category]	26%	26%	38%	25%	0%	25%	35%	25%	30%
South (n)	3,683	3,680	1	1	1	3,337	215	95	36
[% of vision loss category]	43%	43%	8%	25%	100%	43%	40%	35%	42%
West (n)	1,274	1,271	1	2	0	1,157	54	51	12
[% of vision loss category]	15%	15%	8%	50%	0%	15%	10%	19%	14%
Unknown (n)	297	297	0	0	0	233	33	25	6
[% of vision loss category]	3%	3%	0%	0%	0%	304%	6%	9%	7%

Table 2 continued. Baseline demographics using post-index vision loss categorization.

		JAVITT VISION LOSS CATEGORIES				ICD-9 VISION LOSS CATEGORIES			
Characteristic	**Overall cohort**	**None**	**Moderate**	**Severe**	**Blind**	**No vision loss**	**Mild: 365.72**	**Moderate: 365.72**	**Severe: 365.73**
N	8,575	8,557	13	4	1	7,676	542	271	86
(% of N)	100.0%	99.8%	0.1%	0.1%	<0.1%	89.5%	6.3%	3.2%	1.0%
Plan type^									
Comprehensive	337	336	1	0	0	275	30	25	7
EPO	202	201	1	0	0	181	11	8	2
HMO	923	922	0	1	0	840	50	18	15
Non-capitated POS	682	681	1	0	0	639	22	17	4
PPO	5660	5647	9	3	1	5056	377	179	48
POS with capitation	47	47	0	0	0	43	3	0	1
CDHP	420	420	0	0	0	377	14	13	6
HDHP	200	200	0	0	0	174	10	5	1
missing	104	103	1	0	0	91	25	6	2
Employment status*									
Active full time (n)	3,524	3,517	5	2	0	3,350	100	54	20
[% of vision loss category]	41%	41%	38%	50%	0%	44%	18%	20%	23%
Active part time/seasonal (n)	67	67	0	0	0	64	2	1	0
[% of vision loss category]	1%	1%	0%	0%	0%	1%	0%	0%	0%
Early retiree (n)	1,101	1,099	2	0	0	1,014	46	30	11
[% of vision loss category]	13%	13%	15%	0%	0%	13%	8%	11%	13%
Medicare eligible retiree (n)	104	103	0	1	0	91	5	7	1
[% of vision loss category]	1%	1%	0%	25%	0%	1%	1%	3%	1%
Retiree (status unknown) (n)	115	115	0	0	0	105	5	5	0
[% of vision loss category]	1%	1%	0%	0%	0%	1%	1%	2%	0%
COBRA continuee (n)	17	17	0	0	0	17	0	0	0
[% of vision loss category]	< 1%	< 1%	0%	0%	0%	< 1%	0%	0%	0%
Long term disability (n)	15	15	0	0	0	15	0	0	0
[% of vision loss category]	< 1%	< 1%	0%	0%	0%	< 1%	0%	0%	0%
Surviving spouse/dependent (n)	32	32	0	0	0	26	4	2	0
[% of vision loss category]	< 1%	< 1%	0%	0%	0%	< 1%	1%	1%	0%
Other/unknown (n)	3,600	3,592	6	1	1	2,994	370	172	54
[% of vision loss category]	42%	42%	46%	25%	100%	39%	70%	63%	63%

^ plan type acronyms: Exclusive provider organization (EPO); Health maintenance organization (HMO); Point of service (POS); Preferred provider organization (PPO); Consumer driven health plan (CDHP); High deductible health plan (HDHP)

* Employment status of primary insurance holder

Table 3. Number and percentage of patients who shifted vision loss groups from pre- to post-index period.

JAVITT CLASSIFICATION		
	# patients	% of total
No change in vision category	8,545	99.7
Vision loss improved by 1 category	8	0.1
Vision loss improved by 2 categories	6	0.1
Vision loss worsened by 1 category	13	0.2
Vision loss worsened by 2 categories	3	< 0.1

ICD-9 CLASSIFICATION		
	# patients	% of total
No change in vision category	7,762	90.5
Vision loss improved by 1 category	39	0.5
Vision loss improved by 2 categories	2	< 0.1
Vision loss improved by 3 categories	0	0.0
Vision loss worsened by 1 category	463	5.4
Vision loss worsened by 2 categories	232	2.7
Vision loss worsened by 3 categories	77	< 0.1

Table 4.1 Service category frequency and unadjusted mean cost by pre-index vision loss categorization. (Inpatient stays, outpatient office visits, ER claims, medication fills)

		JAVITT CATEGORIES			ICD-9 CATEGORIES			
Variable	**Overall cohort**	**None**	**Mod**	**Severe**	**None**	**Mild**	**Mod**	**Severe**
N	8575	8557	11	7	8411	108	49	7
(% of total N)	100.0%	99.8%	0.1%	0.1%	98.1%	1.2%	0.6%	0.1%
No. Pre-index IP stays	516	516	0	0	508	7	1	0
No. of patients	415	415	0	0	408	6	1	0
Mean cost, USD (95% CI)	$21,227	$21,227	$0	$0	$21,231	$23,030	$9,067	$0
	($18,787, $23,667)	($18,787, $23,667)	- -	- -	($18,755, $23,807)	($7,031, $39,030)	- -	- -
No. Post-index IP stays	604	602	0	2	598	6	0	0
No. of patients	476	474	0	2	470	6	0	0
Mean cost, USD	$25,166	$25,225	$0	$11,071	$25,341	$11,436	$0	$0
(95% CI)	($20,531, $29,801)	($20,571, $29,879)	- -	(-$70,397, $92,539)	($20,650, $30,032)	(-$220, $23,093)	- -	- -
No. Pre-index OP vists (IP files)	5	5	0	0	5	0	0	0
No. of patients	5	5	0	0	5	0	0	0
Mean cost, USD	$189	$189	$0	$0	$189	$0	$0	$0
(95% CI)	($175, $204)	($175, $204)	- -	- -	($175, $204)	- -	- -	- -
No. Post-index OP visits (IP files)	4	4	0	0	4	0	0	0
No. of patients	4	4	0	0	4	0	0	0
Mean cost, USD	$189	$189	$0	$0	$189	$0	$0	$0
(95% CI)	(-$12, $389)	(-$12, $389)	- -	- -	(-$12, $389)	- -	- -	- -
No. Pre-index OP vists (OP files)	43,754	43,661	63	28	42,830	599	257	66
No. of patients	7,457	7,439	11	7	7,313	97	40	7
Mean cost, USD	$356	$355	$530	$378	$355	$379	$350	$534
(95% CI)	($343, $368)	($343, $368)	($246, $814)	($83, $372)	($342, $368)	($295, $463)	($245, $455)	(-$279, $1,347)
No. Post-index OP visits (OP files)	58,939	58,806	84	49	57,712	811	352	64
No. of patients	8,136	8,119	10	7	7,977	105	47	7
Mean cost, USD	$422	$422	$767	$574	$422	$458	$370	$503
(95% CI)	($411, $434)	($410, $434)	($296, $1,238)	($78, $1,070)	($410, $343)	($362, $554)	($278, $461)	(-$12, $1,018)
No. Pre-index ER claims (IP file)	104	104	0	0	104	0	0	0
No. of patients	77	77	0	0	77	0	0	0
Mean cost, USD	$458	$458	$0	$0	$458	$0	$0	$0
(95% CI)	($363, $553)	($363, $553)	- -	- -	($363, $553)	- -	- -	- -
No. Post-index ER claims (IP file)	131	131	0	0	131	0	0	0
No. of patients	100	100	0	0	100	0	0	0
Mean cost, USD	$492	$492	$0	$0	$492	$0	$0	$0
(95% CI)	($325, $658)	($325, $658)	- -	- -	($325, $658)	- -	- -	- -
No. Pre-index ER claims (OP file)	2,206	2,203	0	3	2,142	45	15	4
No. of patients	1,039	1,037	0	2	1,013	18	6	2
Mean cost, USD	$513	$514	$0	$351	$513	$534	$521	$359
(95% CI)	($468, $558)	($468, $559)	- -	(-$2,390, $3,092)	($467, $559)	($345, $722)	(-$106, $1,149)	($168, $550)
No. Post-index ER claims (OP file)	2,661	2,658	0	3	2,604	43	11	3
No. of patients	1,171	1,169	0	2	1,147	16	6	2
Mean cost, USD	$606	$606	$0	$593	$606	$787	$505	$0
(95% CI)	($559, $654)	($559, $654)	- -	(-$2,765, $3,952)	($558, $653)	($451, $1,124)	($122, $887)	- -
No. Pre-index medication fills	141,327	141,004	230	93	138,808	1,593	838	88
No. of patients	6,458	6,444	10	4	6,347	79	29	3
Mean cost, USD	$1,694	$1,694	$1,877	$493	$1,703	$1,059	$1,373	$1,801
(95% CI)	($1,593, $1,795)	($1,593, $1,795)	($160, $3,594)	($52, $934)	($1,601, $1,806)	($701, $1,416)	($676, $2,069)	(-$4,740, $8,342)
No. Post-index medication fills	176,162	175,661	348	153	173,267	1,807	982	106
No. of patients	6,867	6,853	10	4	6,755	77	32	3
Mean cost, USD	$2,066	$2,064	$3,548	$427	$2,075	$1,471	$1,567	$2,152
(95% CI)	($1,936, $2,195)	($1,935, $2,194)	(-$269, $7,364)	(-$308, $1,162)	($1,943, $2,206)	($955, $1,987)	($882, $2,253)	(-$5,346, $9,651)

IP: inpatient OP: outpatient

Note: If there is only one observation, that cost is shown

Table 4.2 Vision related service category frequency and unadjusted mean cost by pre-index vision loss categorization. (Vision related outpatient office visits, glaucoma diagnostic tests, and glaucoma surgery)

		JAVITT CATEGORIES			ICD-9 CATEGORIES			
Variable	**Overall cohort**	**None**	**Mod**	**Severe**	**None**	**Mild**	**Mod**	**Severe**
No. Pre-index vision OP visit (OP file)	4,104	4,083	16	5	4,027	52	22	3
No. of patients	2,595	2,588	3	4	2,538	40	14	3
Mean cost, USD	$93	$93	$222	$80	$93	$79	$88	$34
(95% CI)	($89, $96)	($89, $96)	(-$68, $512)	($18, $141)	($90, $96)	($59, $99)	($47, $129)	(-$49, $117)
No. Post-index vision OP visit (OP file)	14,477	14,435	22	20	14,221	150	97	9
No. of patients	5,655	5,644	5	6	5,548	67	35	5
Mean cost, USD	$140	$140	$247	$213	$140	$122	$128	$127
(95% CI)	($136, $143)	($136, $143)	($60, $433)	($60, $365)	($137, $144)	($100, $145)	($92, $163)	($23, $230)
No. Post-index glaucoma tests (IP file)	1	1	0	0	1	0	0	0
No. of patients	1	1	0	0	1	0	0	0
Mean cost, USD	$26	$26	$0	$0	$26	$0	$0	$0
(95% CI)	- -	- -	- -	- -	- -	- -	- -	- -
No. Pre-index glaucoma tests (OP file)	8,123	8,095	22	6	7,959	111	45	8
No. of patients	3,340	3,330	6	4	3,263	52	22	3
Mean cost, USD	$100	$100	$187	$90	$101	$79	$84	$110
(95% CI)	($97, $103)	($97, $103)	($76, $297)	(-$59, $238)	($97, $104)	($61, $98)	($41, $127)	(-$184, $403)
No. Post-index glaucoma tests (OP file)	17,271	17,227	24	20	16,922	220	114	15
No. of patients	7,225	7,207	11	7	7,081	95	43	6
Mean cost, USD	$104	$104	$129	$192	$104	$99	$104	$96
(95% CI)	($102, $107)	($102, $106)	($59, $199)	($53, $331)	($102, $107)	($81, $118)	($80, $128)	($24, $168)
No. Pre-index glaucoma surgery (OP file)	93	93	0	0	89	2	0	2
No. of patients	59	59	0	0	57	1	0	1
Mean cost, USD	$548	$548	$0	$0	$540	$656	$0	$900
(95% CI)	($414, $681)	($414, $681)	- -	- -	($402, $678)	- -	- -	- -
No. Post-index glaucoma surgery (OP file)	1,709	1,708	1	0	1,666	25	13	5
No. of patients	784	783	1	0	770	8	4	2
Mean cost, USD	$827	$827	$571	$0	$825	$952	$1,027	$812
(95% CI)	($754, $900)	($754, $901)	- -	- -	($750, $899)	($516, $1,388)	(-$133, $2,187)	(-$558, $2,182)

IP: inpatient OP: outpatient

Note: If there is only one observation, that cost is shown. No vision office visit claims found in IP file, no glaucoma tests identified in pre-index period from IP file, no glaucoma surgery claims found in IP file.

Table 4.3. Glaucoma specific service category frequency and unadjusted mean cost by pre-index vision loss categorization. (Glaucoma specific vision related outpatient office visits, glaucoma diagnostic tests, and glaucoma surgery)

		JAVITT CATEGORIES			ICD-9 CATEGORIES			
Variable	**Overall cohort**	**None**	**Mod**	**Severe**	**None**	**Mild**	**Mod**	**Severe**
N	8575	8557	11	7	8411	108	49	7
(% of total N)	100.0%	99.8%	0.1%	0.1%	98.1%	1.2%	0.6%	0.1%
No. Post-index ER claims (OP file)	2	2	0	0	2	0	0	0
No. of patients	1	1	0	0	1	0	0	0
Mean cost, USD	$0	$0	$0	$0	$0	$0	$0	$0
(95% CI)	- -	- -	- -	- -	- -	- -	- -	- -
No. Pre-index OP vists (OP file)	392	390	2	0	389	3	0	0
No. of patients	223	222	1	0	220	3	0	0
Mean cost, USD	$82	$82	$51	$0	$83	$15	$0	$0
(95% CI)	($72, $93)	($72, $93)	- -	- -	($72, $94)	(-$50, $80)	- -	- -
No. Post-index OP visits (OP file)	13,224	13,194	22	8	12,917	215	74	18
No. of patients	5,314	5,303	8	3	5,199	77	33	5
Mean cost, USD	$95	$95	$140	$124	$95	$101	$76	$127
(95% CI)	($92, $97)	($92, $97)	($3, $278)	($29, $218)	($92, $97)	($78, $124)	($52, $100)	($7, $248)
No. Pre-index vision OP visits (OP files)	349	347	0	2	344	3	2	0
No. of patients	226	225	0	1	221	3	2	0
Mean cost, USD	$96	$96	$0	$104	$98	$50	$0	$0
(95% CI)	($86, $106)	($86, $106)	- -	- -	($88, $108)	(-$124, $224)	- -	- -
No. Post-index vision OP visits (OP file)	12,668	12,639	12	17	12,427	139	94	8
No. of patients	5,426	5,415	5	6	5,321	66	35	4
Mean cost, USD	$127	$127	$145	$180	$127	$116	$125	$146
(95% CI)	($124, $130)	($124, $130)	($87, $204)	($23, $337)	($124, $130)	($95, $137)	($89, $161)	($15, $277)
No. Pre-index glaucoma tests (OP file)	786	784	1	1	775	8	3	0
No. of patients	307	305	1	1	301	4	2	0
Mean cost, USD	$123	$124	$0	$96	$126	$21	$0	-
(95% CI)	($112, $135)	($112, $135)	- -	- -	($114, $137)	(-$45, $86)	- -	- -
No. Post-index glaucoma tests (OP file)	15,754	15,719	16	19	15,419	212	108	15
No. of patients	6,984	6,970	8	6	6,841	95	41	6
Mean cost, USD	$98	$98	$76	$213	$98	$95	$101	$96
(95% CI)	($96, $100)	($96, $100)	($26, $126)	($53, $373)	($96, $100)	($76, $113)	($77, $125)	($24, $168)
No. Post-index glaucoma test (IP file)	1	1	0	0	1	0	0	0
No. of patients	1	1	0	0	1	0	0	0
Mean cost, USD	$26	$26	$0	$0	$26	$0	$0	$0
(95% CI)	- -	- -	- -	- -	- -	- -	- -	- -
No. Pre-index glaucoma surgery (OP file)	28	28	0	0	28	0	0	0
No. of patients	19	19	0	0	19	0	0	0
Mean cost, USD	$593	$593	$0	$0	$593	$0	$0	$0
(95% CI)	($418, $769)	($418, $769)	- -	- -	($418, $769)	- -	- -	- -
No. Post-index glaucoma surgery (OP file)	1,602	1,601	1	0	1,559	25	13	5
No. of patients	758	757	1	0	744	8	4	2
Mean cost, USD	$783	$783	$571	$0	$800	$952	$1,027	$812
(95% CI)	($713, $852)	($713, $853)	- -	- -	($709, $850)	($516, $1,388)	(-$133, $2,187)	(-$558, $2,182)
No. Pre-index medication fills	11,564	11,510	37	17	11,314	152	93	5
No. of patients	2,834	2,825	7	2	2,783	38	12	1
Mean cost, USD	$292	$292	$494	$255	$292	$219	$666	$560
(95% CI)	($281, $304)	($280, $304)	(-$66, $1,053)	(-$2,980, $3,490)	($280, $303)	($102, $336)	($242, $1,090)	- -
No. Post-index medication fills	32,034	31,922	72	40	31,436	373	214	11
No. of patients	5,783	5,771	9	3	5,682	69	30	2
Mean cost, USD	$295	$294	$649	$365	$294	$22	$478	$488
(95% CI)	($286, $304)	($285, $303)	($282, $1,016)	(-$766, $1,497)	($285, $303)	($151, $433)	($268, $688)	(-$3,116, $4,091)

IP: inpatient OP: outpatient

Note: If there is only one observation, that cost is shown. No ER claims identified in pre-index period from OP file, no ER claims identified from the IP file, no pre-index glaucoma test claims identified in pre-index period from IP file, no glaucoma surgery claims identified from IP file

Table 5. Post-index unadjusted mean total healthcare cost and glaucoma specific cost by pre-index Javitt vision loss categorization.

		VISION LOSS CLASSIFICATION PRIOR TO INDEX DATE JAVITT CATEGORIES			
Variable	**Overall cohort**	**None**	**Any vision loss**	**Mod**	**Severe**
N	8575	8557	18	11	7
(% of total N)	100.0%	99.8%	0.2%	0.1%	0.1%
Mean pre-index total healthcare cost	$5,405	$5,405	$5,118	$6,287	$3,281
(95% CI)	($5,122, $5,688)	($5,122, $5,689)	($2,277, $7,959)	($1,718, $10,856)	($514, $6,047)
Mean post-index total healthcare cost	$7,106	$7,106	$7,025	$7,146	$6,834
(95% CI)	($6,677, $7,534)	($6,676, $7,535)	($3,038, $11,010)	($1,601, $12,692)	(-$811, $14,479)
Mean pre-index glaucoma specific cost	$107	$107	$234	$319	$101
(95% CI)	($102, $112)	($101, $112)	($11, $457)	(-$36, $674)	(-$147, $350)
Mean post-index glaucoma specific cost	$487	$486	$705	$806	$546
(95% CI)	($475, $498)	($475, $498)	($418, $992)	($373, $1,240)	($132, $960)

"Any vision loss" category is the combination of all vision loss categories in the Javitt classification system

Table 6. Post-index unadjusted mean total healthcare cost and glaucoma specific cost by pre-index ICD-9 vision loss categorization.

		VISION LOSS CLASSIFICATION PRIOR TO INDEX DATE ICD-9 CATEGORIES				
Variable	**Overall cohort**	**None**	**Any vision loss**	**Mild**	**Mod**	**Severe**
N	8575	8411	164	108	49	7
(% of total N)	100.0%	98.1%	2.0%	1.2%	0.6%	0.1%
Mean pre-index total healthcare cost	$5,405	$5,400	$5,634	$6,065	$4,331	$8,094
(95% CI)	($5,122, $5,688)	($5,115, $5,686)	($3,635, $7,633)	($3,384, $8,747)	($1,497, $7,164)	(-$6,234, $22,422)
Mean post-index total healthcare cost	$7,106	$7,132	$5,724	$6,183	$4,344	$4,820
(95% CI)	($6,677, $7,534)	($6,698, $7,567)	($3,446, $8,003)	($3,037, $9,329)	($1,555, $8,132)	($512, $9,127)
Mean pre-index glaucoma specific cost	$107	$107	$105	$80	$163	$80
(95% CI)	($102, $112)	($102, $112)	($57, $152)	($35, $124)	($39, $287)	(-$116, $276)
Mean post-index glaucoma specific cost	$487	$486	$525	$483	$602	$628
(95% CI)	($475, $498)	($475, $498)	($428, $621)	($363, $602)	($417, $789)	($188, $1,069)

"Any vision loss category" is the combination of all vision loss categories in the ICD-9 classification system

Figure 2. Histogram of pre-index (baseline) total healthcare cost.

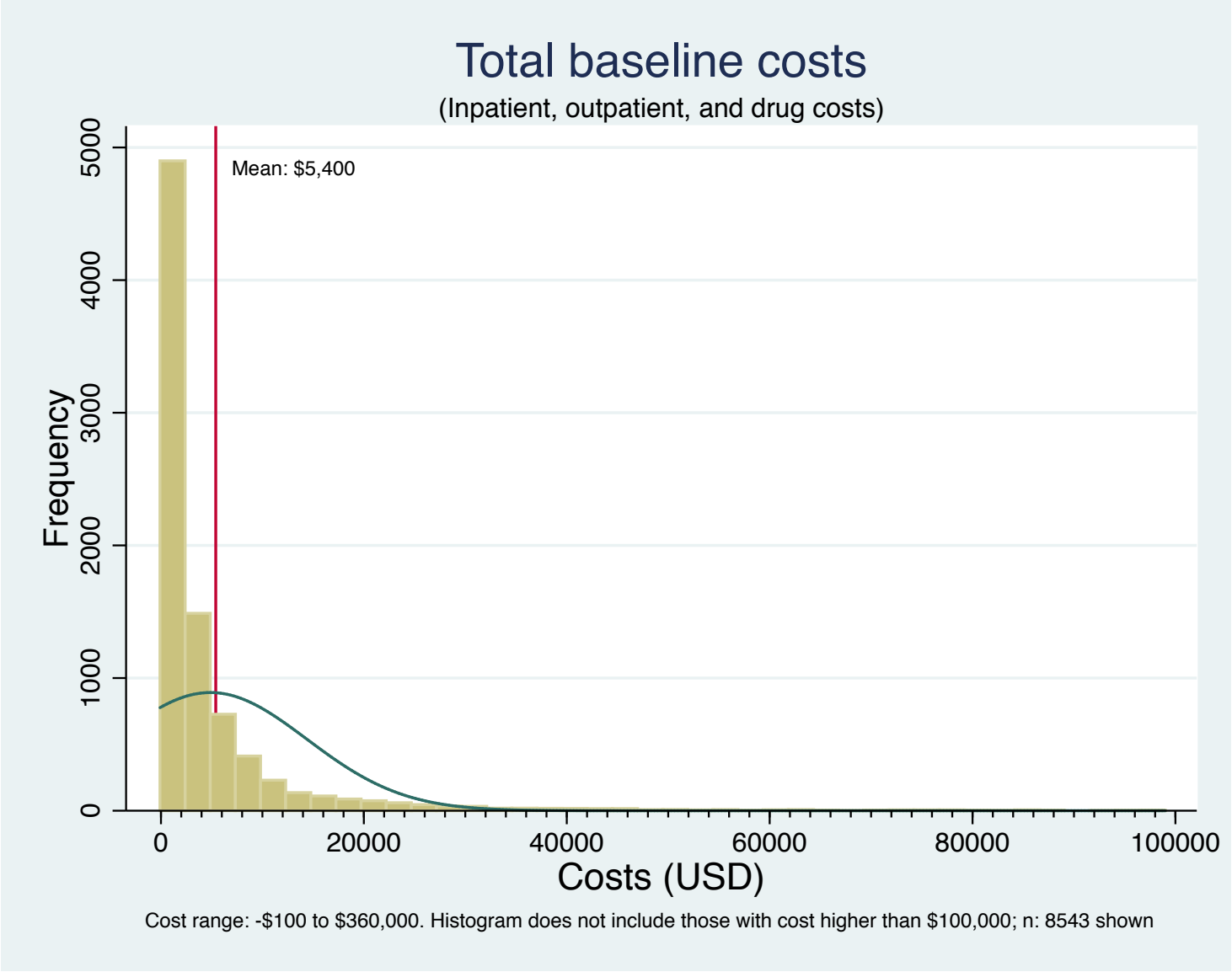

Figure 3. Histogram of post-index (follow up) total healthcare cost.

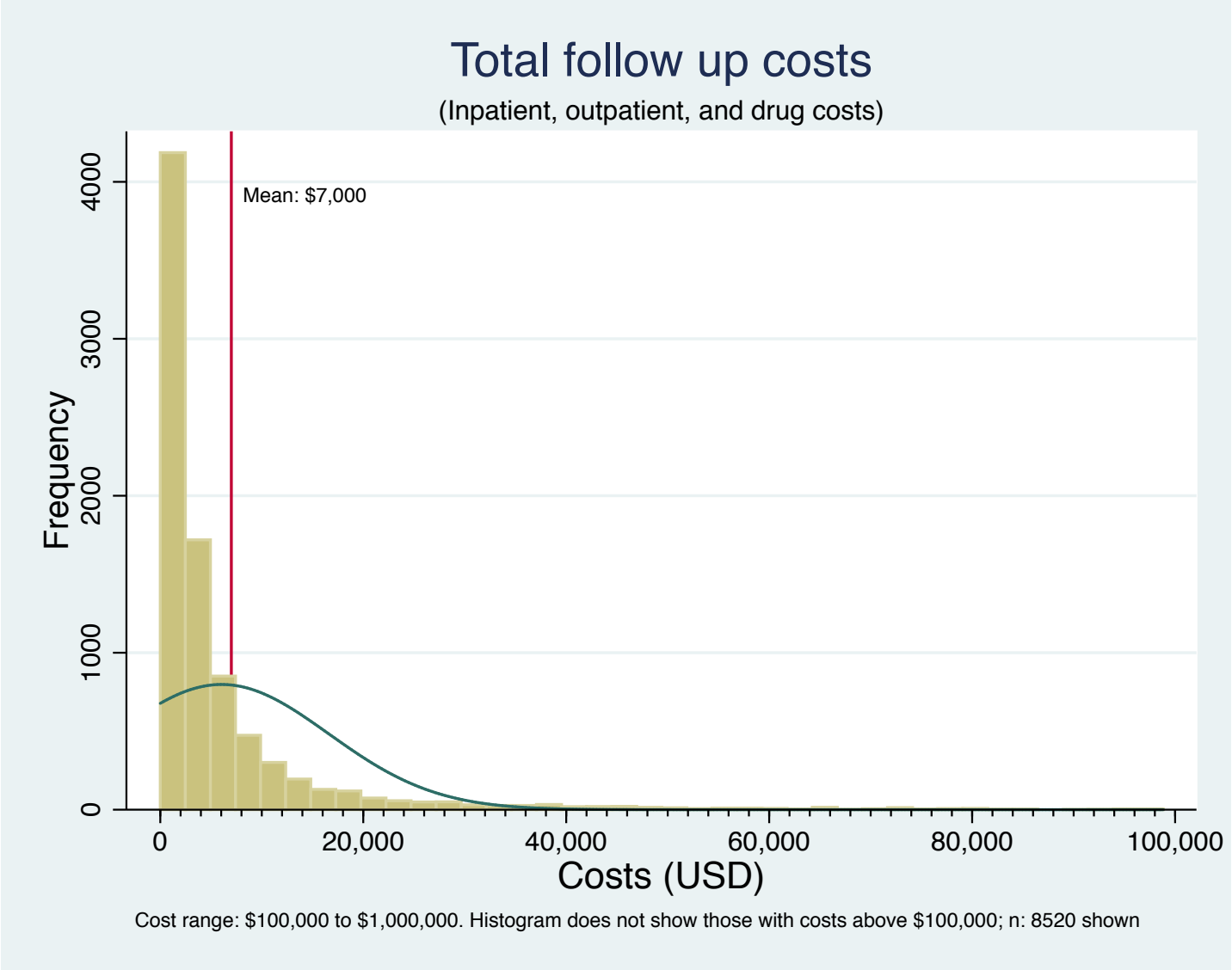

Figure 4. Histogram of pre-index (baseline) glaucoma specific cost.

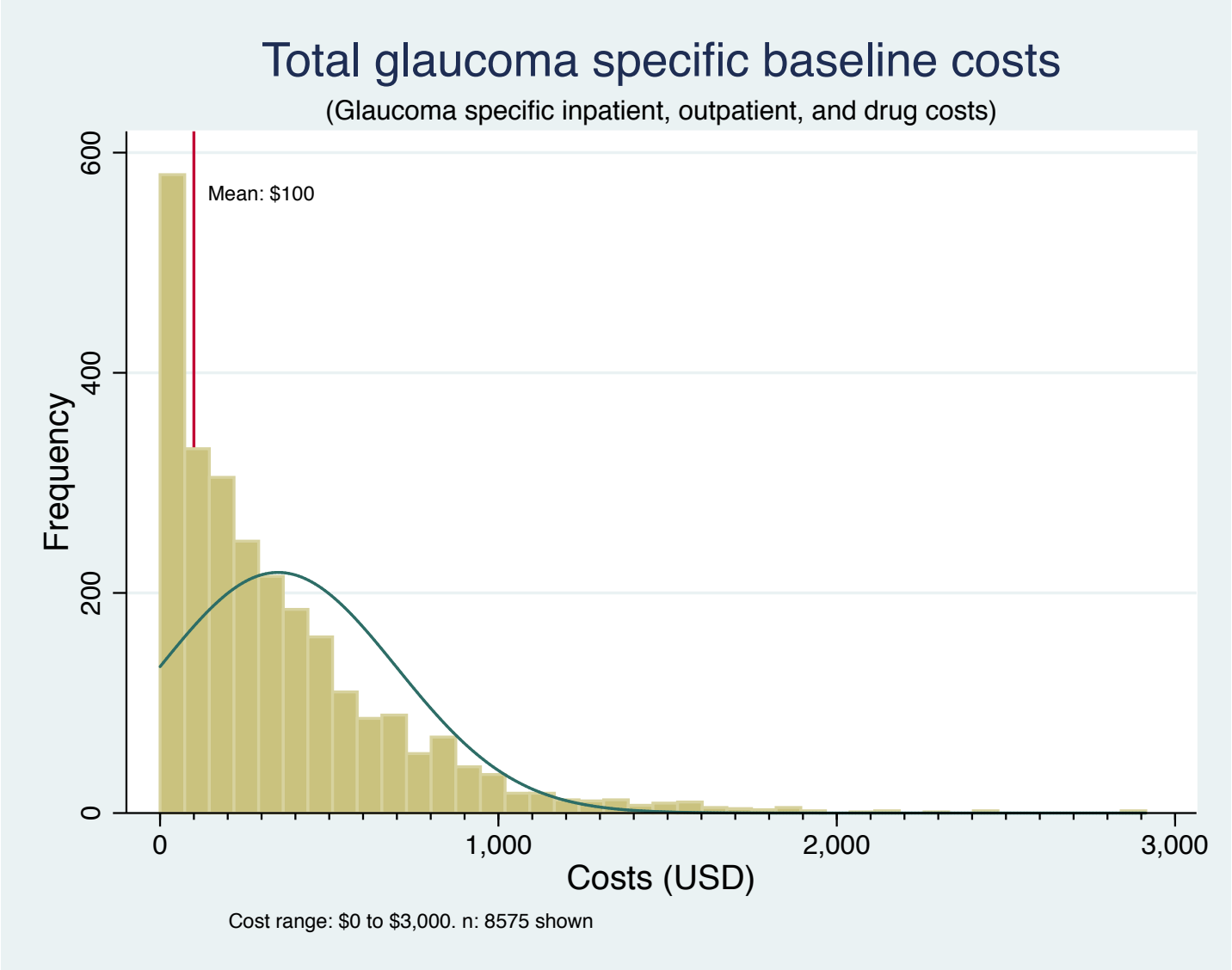

Figure 5. Histogram of post-index (follow up) glaucoma specific cost.

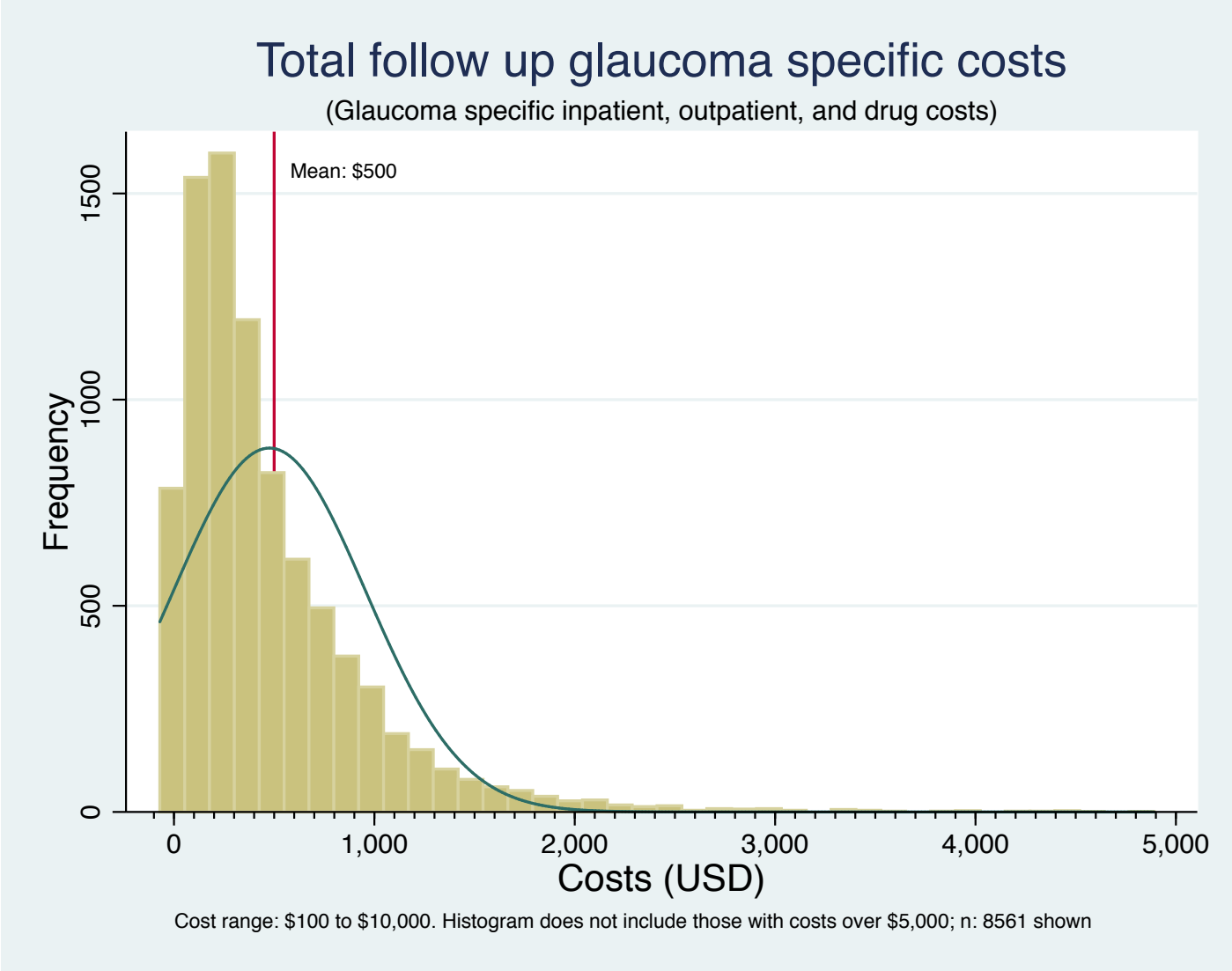

Table 7. Post-index unadjusted and adjusted total healthcare cost ratios for Javitt and ICD-9 vision loss categorization.

TOTAL HEALTHCARE POST-INDEX COST RATIOS				
Javitt vision loss category compared to no vision loss	**Unadjusted Cost ratio**	**SE**	**p-value**	**95% CI**
Any vision loss	0.99	0.26	NS	(.59, 1.66)
Moderate	1.01	0.34	NS	(.52, 1.93)
Severe	0.96	0.41	NS	(.42, 2.21)
Javitt vision loss category compared to no vision loss	**Adjusted cost ratio^**	**SE**	**p-value**	**95% CI**
Any vision loss	1.19	0.49	NS	(.53, 2.66)
Moderate	0.81	0.17	NS	(.53, 1.22)
Severe	1.80	1.20	NS	(.49, 6.66)
ICD-9 vision loss category compared to no vision loss	**Unadjusted Cost ratio**	**SE**	**p-value**	**95% CI**
Any vision loss	0.80	0.16	NS	(.54, 1.2)
Mild	0.87	0.22	NS	(.52, 1.44)
Moderate	0.68	0.23	NS	(.35, 1.31)
Severe	0.68	0.23	NS	(.35, 1.31)
ICD-9 vision loss category compared to no vision loss	**Adjusted cost ratio^**	**SE**	**p-value**	**95% CI**
Any vision loss	0.65	0.08	***	(.51, .82)
Mild	0.64	0.09	**	(.48, .85)
Moderate	0.58	0.09	***	(.42, .79)
Severe	1.24	0.85	NS	(.33, 4.74)

Unadjusted: Generalized linear model (GLM) using gamma family and log link
^GLM adjusted for age group, sex, pre-index cost, plan type, Charlson comorbidity score category, pre-index ocular hypertension, and geographic region
p-value: * = ≤0.05; **= ≤0.01; *** = ≤0.001

Table 8. Post-index unadjusted and adjusted glaucoma specific cost ratios for Javitt and ICD-9 vision loss categorization.

GLAUCOMA SPECIFIC POST-INDEX COST RATIOS				
Javitt vision loss category compared to no vision loss	**Unadjusted Cost ratio**	**SE**	**p-value**	**95% CI**
Any vision loss	1.45	0.27	*	(1.00, 2.1)
Moderate	1.66	0.38	*	(1.06, 2.6)
Severe	1.12	0.32	NS	(.64, 1.97)
Javitt vision loss category compared to no vision loss	**Adjusted Cost ratio^**	**SE**	**p-value**	**95% CI**
Any vision loss	1.30	0.22	NS	(.94, 1.81)
Moderate	1.45	0.29	NS	(.98, 2.16)
Severe	1.07	0.30	NS	(.62, 1.86)
ICD-9 vision loss category compared to no vision loss	**Unadjusted Cost ratio**	**SE**	**p-value**	**95% CI**
Any vision loss	1.08	0.10	NS	(.9, 1.3)
Mild	0.99	0.12	NS	(.78, 1.27)
Moderate	1.24	0.19	NS	(.92, 1.67)
Severe	1.29	0.34	NS	(.77, 2.18)
ICD-9 vision loss category compared to no vision loss	**Adjusted Cost ratio^**	**SE**	**p-value**	**95% CI**
Any vision loss	1.08	0.10	NS	(.9, 1.28)
Mild	0.98	0.12	NS	(.77, 1.23)
Moderate	1.24	0.19	NS	(.93, 1.67)
Severe	1.41	0.34	NS	(.88, 2.28)

Unadjusted: Generalized linear model (GLM) using gamma family and log link
^GLM adjusted for age group, sex, pre-index cost, plan type, Charlson comorbidity score category, pre-index ocular hypertension, and geographic region
p-value: * = ≤0.05; **= ≤0.01; *** = ≤0.001

Table 9. Post-index unadjusted and adjusted total healthcare incremental costs from generalized linear model for Javitt and ICD-9 vision loss categorization.

TOTAL HEALTHCARE POST-INDEX INCREMENTAL COSTS				
Javitt vision loss category compared to no vision loss	**Unadjusted incremental cost**	**SE**	**p-value**	**95% CI**
Any vision loss	-$81	1,849	NS	(-$3,704, $3,543)
Moderate	$41	2,383	NS	(-$4,631, $4,712)
Severe	-$271	2,901	NS	(-$5,947, $5,414)
Javitt vision loss category compared to no vision loss	**Adjusted incremental cost^**	**SE**	**p-value**	**95% CI**
Any vision loss	$1,293	3,295	NS	(-$5,164, $7,751)
Moderate	-$1,307	1,148	NS	(-$3,557, $942)
Severe	$5,410	8,105	NS	(-$10,476, $21,296)
ICD-9 vision loss category compared to no vision loss	**Unadjusted incremental cost**	**SE**	**p-value**	**95% CI**
Any vision loss	-$1,408	1,172	NS	(-$3,704, $888)
Mild	-$950	1,595	NS	(-$4,076, $2,177)
Moderate	-$2,289	1,634	NS	(-$5,491, $914)
Severe	-$2,313	1,645	NS	(-$5,537, $911)
ICD-9 vision loss category compared to no vision loss	**Adjusted incremental cost^**	**SE**	**p-value**	**95% CI**
Any vision loss	-$2,401	557	***	(-$3,491, - $1,310)
Mild	-$2,450	659	***	(-$3,741, - $1,159)
Moderate	-$2,876	646	***	(-$4,142, - $1,610)
Severe	$1,661	5,776	NS	(-$9,660, $12,983)

Generalized linear model (GLM) using gamma family and log link. Margins command used to obtain incremental cost. Reference group is no vision loss.

^GLM adjusted for age group, sex, pre-index cost, plan type, Charlson comorbitidy score category, pre-index ocular hypertension, and geographic region.

p-value: * = ≤0.05; **= ≤0.01; *** = ≤0.001

Table 10. Post-index unadjusted and adjusted glaucoma specific incremental costs from generalized linear model for Javitt and ICD-9 vision loss categorization.

GLAUCOMA SPECIFIC POST-INDEX INCREMENTAL COSTS				
Javitt vision loss category compared to no vision loss	**Unadjusted incremental cost**	**SE**	**p-value**	**95% CI**
Any vision loss	$219	132	NS	(-$41, $478)
Moderate	$320	186	NS	(-$44, $684)
Severe	$60	157	NS	(-$247, $367)
Javitt vision loss category compared to no vision loss	**Adjusted incremental cost^**	**SE**	**p-value**	**95% CI**
Any vision loss	$148	106	NS	(-$61, $356)
Moderate	$219	143	NS	(-$61, $499)
Severe	$36	147	NS	(-$251, $324)
ICD-9 vision loss category compared to no vision loss	**Unadjusted incremental cost**	**SE**	**p-value**	**95% CI**
Any vision loss	$38	49	NS	(-$58, $134)
Mild	-$3	60	NS	(-$121, $115)
Moderate	$115	91	NS	(-$63, $294)
Severe	$142	167	NS	(-$185, $469)
ICD-9 vision loss category compared to no vision loss	**Adjusted incremental cost^**	**SE**	**p-value**	**95% CI**
Any vision loss	$37	47	NS	(-$55, $129)
Mild	-$11	56	NS	($121, $100)
Moderate	$119	90	NS	(-$57, $296)
Severe	$201	167	NS	(-$128, $529)

Generalized linear model (GLM) using gamma family and log link. Margins command used to obtain incremental cost. Reference group is no vision loss.

^GLM adjusted for age group, sex, pre-index cost, plan type, Charlson comorbitidy score category, pre-index ocular hypertension, and geographic region.

p-value: * = ≤0.05; **= ≤0.01; *** = ≤0.001

APPENDIX A.

ICD-9 codes excluded from cohort

ICD-9 Codes to Exclude	Description
360.00-364.99	Disorder of globe, Retinal detachment and defect, Other retinal disorder, Chorioretinal inflammation, scars, and other disorders of choroid, Disorders of iris and ciliary body
365.02	Anatomical narrow angle, primary angle closure suspect
365.06	Primary angle closure without glaucoma damage
365.20-365.89 (not including 365.7x)	Other types of glaucoma
366.00-366.99	Cataract

APPENDIX B.

CPT codes for specified service categories

General office visits	
Description	**CPT code**
Office or other outpatient visit with physician ranging from 15 to 60 min (new patient)	99201, 99202, 99203, 99204, 99205
Office or other outpatient visit with physician lasting longer than 60 min (new patient)	99354, 99355
Office or other outpatient visit that may not require the presence of a physician (established patient, with varying levels of complexity in decision making)	99211, 99212, 99213, 99214, 99215
Consultation services (inpatient or outpatient)	99241, 99242, 99243, 99244, 99245
Emergency Department claims	
Description	**CPT code**
Emergency services (minor to high/life-threatening)	99281, 99282, 99293, 99284, 99285
Diagnostic Glaucoma Tests	
Description	**CPT code**
gonioscopy	92020
visual field test	92081-3
serial tonometry	92100
tonography	92120, 92130
optical coherence tomography	92135
provocative tests for glaucoma	92140
fundus photographs	92250
corneal pachymetry	76514
anterior segment OCT	0187T
ocular blood flow analyzer	0198T
occupational therapy	97003-4, 97532, 97535
Glaucoma surgery	
Surgical Procedure Description	**CPT code**
trabeculectomy ab externo in absence of previous surgery	66170
trabeculectomy ab externo with scarring from previous surgery	66172
tube shunt	66180
Revision or repair of operative wound of anterior segment	66250
ciliary body destruction by endolaser	66711
Scleral reinforcement, with graft	67255
Aquaflow (STAAR Surgical Company, Monrovia, CA) or Express shunt (Alcon Surgical, Ft. Worth, TX), internal or exteral approach	0191T, 0192T
Ciliary body destruction; cyclophotocoagulation transscleral	66710
Revision of aqueous shunt to extraocular reservoir	66185
Canaloplasty	0176T, 0177T
Laser Procedure Description	**CPT code**
Laser trabeculoplasty	65855
Laser iridotomy/iridectomy	66761
Iridoplasty by photocoagulation	66762

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