

Non-adherence to eye care in people with diabetes

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ABSTRACT

Objective Evaluate individual factors that impact adherence to eye care follow-up in patients with diabetes. **Design and methods** A 4-year retrospective chart review was conducted for 1968 patients with diabetes over age 40 from an urban academic center. Data collected included demographics, insurance, visual acuity, smoking status, medications, dates of dilated fundus examinations (DFE), and reported hemoglobin A1C and blood glucose levels. The primary outcome was timely DFE follow-up adherence following the initial eye exam visit. **Results** Overall, 41.6% of patients adhered to initial follow-up eye care recommendations. Multivariable analysis demonstrated that patients with severe diabetic retinopathy (DR) were more adherent than patients with mild DR (OR 1.86). Other variables associated with increased adherence were visual impairment and reported A1C or blood glucose. Smoking was associated with decreased adherence. Ethnicity and insurance were also significantly associated with adherence. Longitudinal follow-up rates were influenced by additional factors, including ethnicity and neighborhood deprivation index. **Conclusions** Patients with moderate to severe DR and/or visual impairment were more likely to adhere to timely DFE follow-up. This could relate to the presence of visual symptoms and/or other systemic manifestations of diabetes. Smokers were less likely to adhere to timely DFE follow-up. One hypothesis is patients who smoke have other symptomatic health problems which patients prioritize over asymptomatic ocular disorders. In order to reduce vision loss from DR, practitioners should be aware that patients with mild and moderate DR, patients with normal vision, and smokers are at greater risk for poor follow-up eye care adherence.

INTRODUCTION

Approximately, 285 million people worldwide have been diagnosed with diabetes.¹ It is estimated that by 2025, 53.1 million Americans will be affected by diabetes, representing a projected increase of 64% from 2010.² Diabetic retinopathy (DR) is the most common complication of diabetes and a leading cause of blindness in the USA and other countries.³ Almost all people with diabetes will develop some degree of DR, with incidence increasing with longer duration of diabetes.⁴ A retinal vascular disorder, DR results in microvascular damage and leads to retinal ischemia and

Significance of this study

What is already known about this subject?

- ▶ Factors known to impact overall eye care utilization include age, ethnicity, socioeconomic status, sex, and insurance status.
- ▶ Less than 60% of Americans with diabetes adhere to recommendations for annual eye exams.

What are the new findings?

- ▶ Multiple factors impacted adherence to eye exams in this population with diabetes, including severity of diabetic retinopathy, ethnicity, and reporting of hemoglobin A1C or blood sugar.
- ▶ Smoking status is a new risk factor impacting adherence in our population.

How might these results change the focus of research or clinical practice?

- ▶ Understanding the risk stratification for adherence in patients with diabetes may impact clinical recommendations.

increased vascular permeability. Estimates of DR and vision-threatening DR prevalence in US adults with diabetes are 28.5% and 4.4%, respectively.⁵ In 2004, blindness from DR accounted for approximately US\$ 500 million in direct medical costs among Americans age 40 and older.⁶ Improving the detection, management, and treatment of DR could save between US\$62.1 and 108.6 million in annual costs to the federal government.⁴ Due to the advancing age of the population and growing rates of obesity across all ethnic groups, the medical and financial costs of diabetes and DR in the USA continue to rise.⁶

Management of DR includes early identification, regular eye examinations, aggressive control of hyperglycemia and hypertension, as well as medical and/or surgical ocular treatment(s). The American Diabetes Association and the American Academy of Ophthalmology recommend dilated fundus examinations (DFEs) for all people with diabetes at least once a year and more frequent exams for more advanced DR.^{7,8} However, only between 50% and 60% of Americans with



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diabetes receive annual DFEs,⁹ with rates even lower in underserved and racial/ethnic minority populations.^{10–12} In order to reduce the prevalence of eye disease and improve patients' quality of life, *Healthy People 2020* aims to increase the proportion of adults with diabetes who have comprehensive eye examinations.⁹ One method to achieve this goal is to implement targeted interventions for patients at risk for low adherence. Studies have shown that age,^{6 12–15} gender,^{12 14 16} ethnicity,^{13–15 17–19} socioeconomic status,^{6 12 14 17 19 20} and insurance coverage^{6 16–18 21–23} affect utilization of eye care services. However, limited research has documented the factors associated with adherence to established recommendations for DFE follow-up. Most research to date assessing DFE adherence has used survey methods.²⁴ Self-reported data are limited not only due to response bias but also in the clinical variables that can be collected. In addition, most research has only assessed whether patients with diabetes receive an annual eye examination and does not take into account the severity of DR.

Therefore, this study aims to (1) identify factors associated with short-term adherence to DFE within a recommended time frame following an index visit for a large cohort of patients with diabetes in an urban eye care setting, (2) identify the factors that impact longitudinal utilization of DFE services and (3) compare the individual, clinical, and system-level factors that impact DFE follow-up adherence by severity of DR. With this data, we aim to identify the characteristics of patients at high risk for poor adherence to DFE follow-up.

RESEARCH DESIGN AND METHODS

Following institutional review board approval, a database was developed using billing and administrative information of patients over age 40 who had their initial visit to a general ophthalmology or retina clinic within an urban academic eye hospital between 1 January 2007 and 12 December 2010. Patients with diabetes were identified in the claims files using International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes for diabetes (250.xx) and/or DR (362.xx). At each encounter, patients were classified by their level of DR

severity (mild, moderate, and severe) in the more severe eye using ICD codes documented in claims (table 1). Patients with diabetes without DR were included in the mild category based on same follow-up recommendations.

Patient charts were reviewed to determine additional clinical information and confirm eligibility. All chart reviewers were research assistants and coordinators trained in the review process using sample charts that had been reviewed by an ophthalmologist. After training, each reviewer's work was evaluated in detail and additional focused training was conducted to assure a standardized chart review process. Patient insurance status from their index visit was recorded from billing data. From the chart review, patients' first reported hemoglobin A1C (HbA1C) and blood sugar levels, age, gender, ethnicity, current smoking status, prescription for glasses, visual acuity, diagnosis of other eye diseases, dates of DFEs, and medications were recorded. Medications noted included insulin, non-insulin diabetes medication, medications to treat hypertension, medications to treat hyperlipidemia, and medications to treat the mental health conditions of anxiety and/or depression. An investigator with a doctorate in pharmacy compiled the list of all medications for each category. Best-corrected visual acuity (BCVA) in the worse eye was categorized as normal vision (20/60 or better) or visual impairment (20/70 or worse). Driving distance is calculated based on the calculations using the eye clinic and patient addresses. Socioeconomic status was estimated using a patient's home census tract based on a previously described standardized neighborhood deprivation index.²⁵ If ethnicity was not recorded in the chart, reviewers obtained it from the patient's driver's license when available. When ethnicity could not be determined from the chart or the driver's license, it was imputed using a previously validated approach based on patients' last names and 2010 Census tract location.^{26 27}

The index visit was defined as the date of the first DFE in this eye care system including a diagnosis of type 1 or type 2 diabetes or DR. Patients who did not have a documented DFE at the designated eye clinics within 30 days of type 1/type 2 diabetes or DR noted

Table 1 ICD-9 codes and American Academy of Ophthalmology recommended follow-up times for patients with diabetes stratified by severity of diabetic retinopathy^a

Category	ICD-9 code and diagnosis	Recommended DFE follow-up	Acceptable DFE follow-up
Mild	250.00 (DM) 362.01 Background NPDR 352.03 NOS NPDR	12 months	15 months
Moderate	362.04 Mild NPDR 362.05 Moderate NPDR	6–12 months	12 months
Severe	362.06 Severe NPDR 362.02 PDR	2–4 months	4 months

DFE, dilated fundus examination; DM, diabetes mellitus; ICD-9, International Classification of Diseases, Ninth Revision; NOS, not otherwise specified; NPDR; non-proliferative diabetic retinopathy; PDR, proliferative diabetic retinopathy.

in their billing records were removed from the sample, as we were unable to define the index visit and hence the recommended follow-up time for these individuals. The diagnosis of diabetes did not have to be new to the patients. For the short-term adherence measure, subjects were defined as adherent if they obtained a DFE within the recommended time after their index visit. Acceptable follow-up was defined as within 15 months for mild DR, within 12 months for moderate DR and within 4 months from the index visit for severe DR (table 1).

This study also assessed longitudinal utilization of DFE services. Longitudinal utilization was measured by the number of DFEs per year over the 4-year study. After the index visit, the severity of DR and the date of each DFE follow-up visit were recorded over the 4-year period.

Data analysis

Descriptive statistics (frequencies, ranges, mean, SD) were calculated to summarize the sample characteristics. Associations between individual, clinical, system information, and DFE follow-up adherence were evaluated using χ^2 tests. Logistic regression was used to evaluate the adjusted impact of individual, clinical, and system-level factors related to DFE follow-up adherence. All variables associated with adherence in the univariable analyses ($p < 0.20$) were included in the multivariable logistic regression model, and a backward elimination procedure was used to sequentially remove non-significant terms until all variables had $p < 0.20$. The number of DFEs over the entire follow-up period was modeled using Poisson regression with follow-up time as the offset term. The same variable selection procedure was used to develop a multivariable model as used for initial DFE adherence. Final multivariable logistic and Poisson models were developed for the entire cohort, for subjects classified with mild DR at the index visit, and for subjects classified with severe DR at the index visit. The distribution of time from index visit to first follow-up DFE was estimated using the Kaplan-Meier method. All analyses were performed using SAS V.9.2 or later (SAS Institute, Cary, North Carolina, USA).

RESULTS

Billing data indicated that 2238 patients with diabetes had an initial visit at the general ophthalmology or retina clinic between 1 January 2007 and 31 December 2010. Charts of 2179 patients were available for review. Additional patients were excluded who had a visit prior to 2007 ($n=23$), no DFE within 30 days of the index visit ($n=128$), or insufficient time between the index visit and review date to allow for recommended follow-up ($n=60$), leaving a total of 1968 patients included in this study. The mean age of included patients was 59.4 years (SD 10.9 years) with a range of 40–93 years. The median of follow-up time was 2.74 years (range of 0.70–5.72 years).

Adherence to initial DFE follow-up

Overall, 41.6% of individuals were adherent to the initial recommended follow-up DFE after the index visit with an average of 0.61 DFEs per year over the entire follow-up period. Adherence to initial DFE follow-up and longitudinal utilization of DFE services were evaluated by patient characteristics (table 2). For initial DFE follow-up, severity of DR was significantly associated with adherence ($p < 0.0001$), with patients with mild DR being the least likely to follow-up in a timely manner. Over the 4-year period, 35.1% of patients with mild or no DR completed DFEs within the recommended follow-up time period (15 months) compared with 44.0% of patients with moderate DR (12 months) and 65.4% of patients with severe DR (4 months). The median time to initial follow-up was 21 days for severe patients, 127 days for moderate patients, and 246 days for mild patients. Patients under 65 years were less likely to adhere to follow-up recommendations than those over 65 ($p=0.0043$). Patients with visual impairment in the worse eye were more adherent to follow-up than patients with normal vision ($p < 0.0001$). Ethnicity also impacted adherence ($p=0.0047$) with adherence ranging from 40.73% to 47.37% by group. Smokers were less likely to follow-up than non-smokers ($p < 0.0001$). Other factors that were significantly associated with adherence to first DFE follow-up in the univariable analyses included the presence of HbA1C documentation ($p < 0.0001$), blood sugar documentation ($p < 0.0001$), insulin use ($p < 0.0001$), diagnosis of cataract ($p < 0.0001$), glaucoma ($p=0.0053$), non-diabetic retinal disease ($p < 0.0001$), and other ocular comorbidities ($p < 0.0001$). Insurance status ($p=0.0008$) was significantly associated with adherence with patients with Medicaid coverage having the lowest adherence for the first DFE follow-up. Absence of mental health medication use was also associated with higher adherence ($p=0.013$).

Longitudinal utilization of DFE services

As for adherence to DFE follow-up, severity of DR ($p < 0.0001$), visual impairment in the worse eye ($p < 0.0001$), HbA1C documentation ($p < 0.0001$), blood sugar documentation ($p < 0.0001$), smoking status ($p < 0.0001$), insurance ($p=0.0095$), insulin use ($p < 0.0001$), mental health medicine use ($p < 0.0001$), non-diabetic retinal disease diagnosis ($p < 0.0001$), and other ocular comorbidity diagnosis ($p < 0.0001$) were significantly associated with number of DFEs per year in the univariable analysis (table 2). Insurance through Medicaid, current smoking and mental health medicine use were associated with lower utilization. The presence of all other factors was associated with higher use. In addition, ethnicity ($p=0.0047$), prescription for glasses ($p=0.0001$), neighborhood deprivation index ($p=0.0057$), hyperlipidemia medication use ($p=0.047$), and driving distance ($p=0.0066$) were associated with number of DFEs per year but not with initial DFE follow-up. Patients of Asian race/ethnicity had the higher utilization than other groups as did those in the

Table 2 DFE follow-up and longitudinal utilization univariable analysis by patient characteristics

Variable	Values	n	Adherence to initial follow-up		Number of DFEs per year over entire follow-up period	
			n (%)	p Value	Mean (95% CI)	p Value
Severity	Severe	393	257 (65.39)	<0.0001	1.45 (1.34 to 1.58)	<0.0001
	Moderate	107	47 (43.93)		0.54 (0.42 to 0.71)	
	Mild	1468	515 (35.08)		0.39 (0.36 to 0.43)	
Gender	F	1077	432 (40.11)	0.13	0.58 (0.54 to 0.64)	0.16
	M	890	387 (43.48)		0.64 (0.58 to 0.70)	
Age	<65	1369	541 (39.52)	0.0043	0.61 (0.57 to 0.66)	0.70
	≥ 65	599	278 (46.41)		0.60 (0.53 to 0.67)	
Ethnicity/race	African-American	1321	538 (40.73)	0.58	0.57 (0.53 to 0.62)	0.0047
	Asian	76	36 (47.37)		0.93 (0.72 to 1.19)	
	Caucasian	391	164 (41.94)		0.59 (0.51 to 0.68)	
	Latino/Hispanic	139	62 (44.6)		0.69 (0.55 to 0.86)	
BCVA in worse eye	Normal vision (20/60 or better)	1369	455 (33.24)	<0.0001	0.44 (0.40 to 0.48)	<0.0001
	Visual impairment (20/70 or worse)	537	339 (63.13)		1.05 (0.96 to 1.15)	
HbA1c in chart	Yes	482	244 (50.62)	<0.0001	0.90 (0.82 to 1.00)	<0.0001
	No	1486	575 (38.69)		0.51 (0.48 to 0.56)	
Blood sugar in chart	Yes	1350	612 (45.33)	<0.0001	0.70 (0.65 to 0.75)	<0.0001
	No	618	207 (33.5)		0.42 (0.36 to 0.48)	
Wears glasses	Yes	1257	500 (39.78)	0.11	0.54 (0.5 to 0.59)	0.0001
	No	675	294 (43.56)		0.7 (0.64 to 0.78)	
Current smoking status	Yes	406	117 (28.82)	<0.0001	0.4 (0.33 to 0.47)	<0.0001
	No	1537	697 (45.35)		0.67 (0.63 to 0.72)	
Insurance	No insurance	340	147 (43.24)	0.0008	0.69 (0.6 to 0.8)	0.0095
	Medicaid	555	199 (35.86)		0.52 (0.45 to 0.59)	
	Medicare	413	204 (49.39)		0.66 (0.58 to 0.75)	
	Medicaid+Medicare	40	14 (35)		0.4 (0.23 to 0.71)	
	Private/other/vision	620	255 (41.13)		0.62 (0.55 to 0.69)	
Neighborhood deprivation index	1 (low SES)	1375	561 (40.8)	0.27	0.58 (0.54 to 0.63)	0.0057
	2	345	146 (42.32)		0.75 (0.65 to 0.85)	
	3	138	68 (49.28)		0.49 (0.38 to 0.64)	
	4 (high SES)	110	44 (40)		0.62 (0.47 to 0.81)	
Medications (insulin)	Yes	571	280 (49.04)	<0.0001	0.75 (0.68 to 0.83)	<0.0001
	No	1397	539 (38.58)		0.55 (0.51 to 0.59)	
Medications (diabetes)	Yes	1507	624 (41.41)	0.73	0.59 (0.55 to 0.64)	0.13
	No	461	195 (42.3)		0.66 (0.58 to 0.75)	
Medications (hypertension)	Yes	1230	522 (42.44)	0.34	0.60 (0.55 to 0.65)	0.54
	No	738	297 (40.24)		0.62 (0.56 to 0.69)	
Medications (hyperlipidemia)	Yes	742	322 (43.4)	0.21	0.56 (0.5 to 0.62)	0.047
	No	1226	497 (40.54)		0.64 (0.59 to 0.69)	
Medications (mental health)	Yes	242	83 (34.30)	0.013	0.41 (0.33 to 0.51)	<0.0001
	No	1666	712 (42.74)		0.64 (0.60 to 0.68)	

Continued

Table 2 Continued

Variable	Values	n	Adherence to initial follow-up		Number of DFEs per year over entire follow-up period	
			n (%)	p Value	Mean (95% CI)	p Value
Driving distance	0–5 miles	665	278 (41.8)	0.40	0.52 (0.47 to 0.59)	0.0066
	5–25 miles	1116	455 (40.77)		0.66 (0.6 to 0.71)	
	≥25 miles	187	86 (45.99)		0.62 (0.51 to 0.76)	
Cataract	Yes	321	168 (52.34)	<0.0001	0.67 (0.57 to 0.78)	0.21
	No	1647	651 (39.53)		0.60 (0.56 to 0.64)	
Glaucoma	Yes	192	98 (51.04)	0.0053	0.68 (0.56 to 0.82)	0.26
	No	1776	721 (40.6)		0.60 (0.56 to 0.64)	
Non-diabetic retinal disease	Yes	203	156 (76.85)	<0.0001	1.46 (1.3 to 1.64)	<0.0001
	No	1765	663 (37.56)		0.5 (0.47 to 0.54)	
Other ocular comorbidity	Yes	1222	568 (46.48)	<0.0001	0.71 (0.65 to 0.76)	<0.0001
	No	746	251 (33.65)		0.46 (0.41 to 0.51)	

Bold indicates p values that reach significance.

DFE, dilated fundus exam; BCVA, best-corrected visual acuity; HbA1c, hemoglobin A1c; SES, socioeconomic status.

second quartile of SES, those closest to Wills, and those not using hyperlipidemia medications.

Multivariable analysis of factors affecting initial DFE follow-up overall and by severity of DR

In the final multivariable logistic regression model of the full cohort, severity of DR, visual impairment in the worse eye, HbA1C documentation, blood sugar documentation, smoking status, diagnosis of cataract, glaucoma, non-diabetic retinal disease, and other ocular comorbidities were significantly associated with initial DFE follow-up adherence (table 3). Patients with severe DR had 1.86 times (95% CI 1.39 to 2.50) higher odds of adherence to initial follow-up recommendations than patients with mild DR.

Patients with severe DR, over age 65 were less likely than younger patients to follow-up (OR 0.57; 95% CI 0.33 to 1.00). In patients with mild DR, visual impairment in the worse eye ($p<0.0001$), HbA1C documentation ($p<0.0001$), blood sugar documentation ($p<0.0001$), negative smoking status ($p<0.0001$), diagnosis of cataract ($p=0.012$), glaucoma ($p=0.032$), non-diabetic retinal disease ($p<0.0001$), or other ocular comorbidities ($p=0.0032$) were associated with a higher likelihood of adhering to initial DFE follow-up recommendations. In patients with severe DR, only age ($p=0.049$), visual impairment in the worse eye ($p=0.0018$), blood sugar documentation ($p=0.0038$), and non-diabetic retinal disease diagnosis ($p=0.030$) were associated with increased likelihood of adherence to initial DFE follow-up.

Multivariable analysis of factors affecting longitudinal utilization overall and by severity of DR

In the full sample, the multivariable Poisson regression model for longitudinal utilization revealed that severity of DR ($p<0.0001$), ethnicity ($p=0.028$), visual impairment in the worse eye ($p<0.0001$), HbA1C documentation

($p<0.0001$), blood sugar documentation ($p<0.0001$), smoking status ($p<0.0001$), non-diabetic retinal disease ($p<0.0001$), other ocular comorbidities ($p<0.0001$), and neighborhood deprivation index (NDI) ($p=0.032$) were associated with longitudinal utilization of DFE services (table 4). Patients with severe DR had 2.77 times (95% CI 2.36 to 3.24) as many DFE appointments per year compared with patients with mild or no DR. Patients with visual impairment in the worse eye had 1.37 times (95% CI 1.19 to 1.57) as many DFE appointments per year as patients with normal vision. Patients with HbA1C and blood sugar documentation had 1.65 times (95% CI 1.47 to 1.86 and 1.43 to 1.89) as many DFE appointments as patients without documentation, respectively. Patients who smoke had 0.72 times (95% CI 0.61 to 0.85) as many DFEs per year as non-smokers.

When stratifying by severity, ethnicity ($p=0.0052$), visual impairment in the worse eye ($p<0.001$), NDI ($p=0.015$), and diagnosis of other ocular comorbidity ($p=0.0006$) were associated with longitudinal utilization in patients with mild DR but not in patients with severe disease. All factors associated with longitudinal utilization in patients with severe DR were also associated with longitudinal utilization in patients with mild DR.

CONCLUSIONS

In our sample, rates of adherence to follow-up DFE recommendations were disappointingly low across all ages and ethnic groups, ranging from 35% to 65% adherence depending on the severity of DR. Longitudinal utilization was also below recommendations, with the annual DFE rate being substantially less than 1 DFE per year for patients with mild and moderate DR and less than 2 DFEs per year for patients with severe DR.

Table 3 Final multivariable logistic regression models for initial DFE follow-up adherence

Variable	All patients			Mild			Severe		
	Adjusted OR	p Value		Adjusted OR	p Value		Adjusted OR	p Value	
Severity (vs. mild*)									
Moderate	1.08 (0.69, 1.69)	0.0002		N/A					
Severe	1.86 (1.39, 2.50)								
Gender (male vs female*)	1.16 (0.94, 1.43)	0.16		1.24 (0.97, 1.58)	0.085		†		
Age (≥65 vs <65*)	†			†			0.57 (0.33, 1.00)	0.049	
BCVA in worse eye (visual impairment vs normal*)	2.38 (1.84, 3.08)	<0.0001		2.42 (1.76, 3.32)	<0.0001		2.21 (1.34, 3.64)	0.0018	
Insurance (vs no insurance*)									
Medicaid	1.04 (0.75, 1.43)	0.15		0.92 (0.63, 1.35)	0.058*		1.26 (0.65, 2.45)	0.11*	
Medicare	1.39 (1.00, 1.94)			1.25 (0.84, 1.86)			2.10 (1.04, 4.27)		
Medicaid and Medicare	0.79 (0.37, 1.70)			0.71 (0.29, 1.72)			1.82 (0.23, 14.3)		
Private/other/Vision	1.01 (0.74, 1.37)			0.76 (0.52, 1.10)			2.10 (1.15, 3.86)		
HbA1c in chart (yes vs no*)	1.74 (1.37, 2.21)	<0.0001		1.98 (1.51, 2.60)	<0.0001		†		
Blood sugar in chart (yes vs no*)	1.82 (1.45, 2.29)	<0.0001		1.89 (1.43, 2.49)	<0.0001		2.01 (1.25, 3.22)	0.0038	
Current smoking status (smoker vs no*)	0.54 (0.41, 0.71)	<0.0001		0.54 (0.39, 0.73)	<0.0001		†		
Medications (mental health) (yes vs no*)	†			†			0.48 (0.20, 1.12)	0.089	
Wears glasses (yes vs no*)	†			1.21 (0.93, 1.59)	0.16		†		
Cataract (yes vs no*)	1.53 (1.16, 2.01)	0.0023		1.50 (1.09, 2.05)	0.012		†		
Glaucoma (yes vs no*)	1.45 (1.04, 2.03)	0.029		1.54 (1.04, 2.28)	0.032		†		
Non-diabetic retinal disease (yes vs no*)	3.77 (2.57, 5.51)	<0.0001		5.77 (3.41, 9.78)	<0.0001		1.95 (1.07, 3.57)	0.030	
Other ocular comorbidity (yes vs no*)	1.52 (1.22, 1.89)	0.0001		1.46 (1.13, 1.87)	0.0032		1.61 (0.97, 2.67)	0.063	

*Reference group.

†Removed from final model via backwards elimination (p>0.2).

BCVA, best-corrected visual acuity; DFE, dilated fundus exam; HbA1c, hemoglobin A1c.

Table 4 Final multivariable Poisson regression models for total number of DFEs over the follow-up period

Variable	All patients		Mild		Severe		
	Adjusted IRR	p Value	Adjusted IRR	p Value	Adjusted IRR	p Value	
Severity (vs mild*)	Moderate Severe	1.30 (0.96, 1.76) 2.77 (2.36, 3.24)	<0.0001				
Gender (male vs female*)		1.10 (0.99, 1.23)	0.085	†		†	
Ethnicity/race (vs African-American*)	Asian	1.22 (0.91, 1.63)	0.028	0.86 (0.54, 1.38)	0.0052	1.55 (0.97, 2.47)	0.14
	Caucasian	0.84 (0.69, 1.03)		0.76 (0.58, 0.99)		0.98 (0.68, 1.43)	
	Latino/Hispanic	1.07 (0.83, 1.37)		1.30 (0.97, 1.74)		0.95 (0.58, 1.55)	
Age (≥65 vs <65*)		†		1.11 (0.96, 1.29)	0.15	0.81 (0.63, 1.05)	0.10
BCVA in worse eye (visual impairment vs normal*)		1.37 (1.19, 1.57)	<0.0001	1.54 (1.31, 1.81)	<0.0001	†	
HbA1C documented (yes vs no*)		1.65 (1.47, 1.86)	<0.0001	1.71 (1.48, 1.97)	<0.0001	1.54 (1.21, 1.97)	0.0006
Blood sugar documented (yes vs no*)		1.65 (1.43, 1.89)	<0.0001	1.62 (1.36, 1.93)	<0.0001	1.55 (1.20, 2.00)	0.0006
Wears glasses (yes vs no*)		1.12 (0.99, 1.26)	0.072	†		†	
Current smoking status (smoker vs no*)		0.72 (0.61, 0.85)	<0.0001	0.76 (0.63, 0.91)	0.0020	0.70 (0.49, 1.01)	0.049
Medication (Insulin) (yes vs no*)		1.10 (0.97, 1.26)	0.15	1.14 (0.99, 1.33)	0.076	†	
Non-insulin diabetic medication (yes vs no*)		0.87 (0.75, 1.01)	0.069	†		†	
Medications (mental health) (yes vs no*)		0.82 (0.67, 1.01)	0.051	†		0.60 (0.34, 1.08)	0.070
Cataract (yes vs no*)		1.12 (0.97, 1.30)	0.13	1.16 (0.98, 1.38)	0.090	†	
Glaucoma (yes vs no*)		†		1.23 (0.99, 1.53)	0.067	†	
Non-diabetic retinal disease (yes vs no*)		1.71 (1.49, 1.96)	<0.0001	2.27 (1.89, 2.73)	<0.0001	1.38 (1.09, 1.74)	0.0089
Other ocular comorbidity (yes vs no*)		1.27 (1.13, 1.44)	<0.0001	1.28 (1.11, 1.47)	0.0006	†	
Neighborhood deprivation index (vs lowest quartile)	Moderately low	1.17 (0.97, 1.41)	0.032	1.08 (0.86, 1.36)	0.015	1.17 (0.81, 1.70)	0.20
	Moderately high	0.81 (0.59, 1.12)		0.96 (0.68, 1.38)		0.70 (0.36, 1.35)	
	High	0.95 (0.68, 1.33)		0.54 (0.31, 0.93)		1.17 (0.67, 2.05)	
Driving distance (vs 0–5 miles)	5–25 miles	1.01 (0.87, 1.17)	0.15	†		1.10 (0.80, 1.51)	0.10
	≥25 miles	0.83 (0.64, 1.07)				0.76 (0.47, 1.22)	

*Reference group.

†Removed from final model via backwards elimination ($p > 0.2$).

Bold indicates p values that reach significance.

BCVA, best-corrected visual acuity; DFE, dilated fundus exam; HbA1c, hemoglobin A1c; IRR, incidence rate ratio.

For over two decades, it has been well known that early identification and treatment can prevent at least 50% of severe vision loss in patients with DR.²⁸ Previous studies have evaluated eye care utilization associations

on a population level based on self-reported data, but this is the first study to analyze clinical and demographic characteristics of patients who do and do not adhere to follow-up DFE guidelines in a large, urban academic

setting. This is also the first study to examine DFE adherence by severity of DR and the individual, clinical, and system-level factors that impact longitudinal utilization of DFE services.

Statistically significant variables after adjustment

Our results indicate that severity of DR is independently and strongly associated with adherence to timely DFEs. Specifically, patients with mild or no DR were the least likely to adhere to follow-up recommendations. We hypothesize several reasons for this association. First, patients with mild DR might not seek regular ophthalmic care because of a lack of perceived need—particularly because visual symptoms may be minimal or absent and lower severity of DR is associated with fewer systemic manifestations.²⁹ In addition, up to half of individuals with moderate-to-severe visual loss do not seek regular eye care because they do not perceive a need for care.^{18 30} It is also possible that patients in our study with mild or no DR had less contact with medical professionals perhaps due to being generally younger and having less time available due to competing commitments (eg, work or family). Thus, they may have less encouragement to regularly follow-up with their eye care provider. Lastly, there could be other factors not yet explored. Therefore, this association identifies a population that can be targeted with educational interventions to increase rates of eye care utilization among people with diabetes.

Population-based studies have consistently found diabetic eye care utilization to be associated with visual impairment.^{12–14} In our population, after adjusting for known risk factors, patients with visual impairment were more likely than patients with normal vision to adhere to initial follow-up DFE recommendations and use DFE services longitudinally. Presumably, visual loss motivates patients to obtain eye care.

Our study is also the first to find a relationship between smoking status and adherence with diabetic eye care: smokers were less likely than non-smokers to adhere to the recommended DFE follow-up and smokers had lower longitudinal utilization of DFE services, even when controlling for other variables. Smoking is related to multiple microvascular complications of diabetes, although smoking's specific effect on retinopathy has not been well defined.³¹ Smoking has also been directly linked to two of the leading causes of vision loss, cataracts, and macular degeneration,³² and may contribute to glaucoma.³³ Smokers have been shown to use more healthcare services at a higher cost than non-smokers, which is in contrast to our findings of lower eye care utilization among individuals with diabetes who smoke.³⁴ It is unclear why smoking is independently associated with less follow-up adherence. Perhaps, patients who smoke have other symptomatic health problems which patients give priority over asymptomatic or less symptomatic ocular disorders. People with diabetes who smoke may place less value on eye care given that smokers have worse overall health compared with non-smokers, leading to other

illnesses superseding the perceived need for eye examinations.³⁵ Smokers also tend to be less educated than non-smokers and may not understand the importance of known health recommendations, which may contribute to the differences between the groups.³⁶ Additionally, self-management of diabetes is difficult, as attested to in multiple studies and addictions such as nicotine may impact self-management strategies.

Whether or not self-reported HbA1C or blood glucose was mentioned in a patient's chart was found to be significantly associated with DFE adherence rates and with increased longitudinal utilization, which was unexpected.³⁷ Since HbA1C and blood glucose were from patient's self-report, it is possible that these patients are, in general, more informed and involved in their healthcare and therefore more likely to adhere to recommendations. However, since three-quarters of our patients were missing HbA1C values and one-third of patients were missing blood glucose, we did not evaluate relationships between level of HbA1C or blood glucose and adherence or other variables. While an objective marker of diabetes control would have been useful, the data could not be correlated with actual HbA1C or blood glucose, as it was subject to recall bias.

Caucasian ethnicity has been associated with higher rates of DFEs compared with African-Americans and Latinos with diabetes,^{10 13 14 16 18} which is particularly concerning as African-Americans and Latinos are projected to have the largest increase in prevalence of diabetic eye disease.⁶ However, ethnic status has not been found to be independently associated with DFE rates in all studies.¹¹ In this current investigation, there was only an association between ethnicity and longitudinal utilization in patients with mild DR, with Asians having the most DFEs per year. Adherence to follow-up recommendations was consistently low across all ethnic/racial groups as shown in table 2.

Non-statistically significant variables after adjustment

Insurance status is another variable that has been associated with DFE rates in population studies with sizeable proportions of patients without insurance status or access to free care.^{12 16–18 21 24} One study also found that among individuals with diabetes over 65 years of age, people who were dual eligible for Medicare and Medicaid were significantly less likely to receive DFEs compared with people eligible for Medicare alone (63% vs 75%; $p < 0.0001$).²⁰ We found insurance status to be associated with adherence rates and longitudinal utilization in the univariable analysis, with Medicaid patients having the lowest adherence rates and Medicare patients having the highest adherence rates. However, this association was not significant in multivariable analyses.

Several previous studies have found higher socioeconomic status (SES) to be associated with having DFEs.^{11 12 24} In a national representative sample of 84572 people, Brechner *et al* found that in people with insulin-dependent diabetes and annual incomes

over US\$40 000, 72.9% had DFEs within the last year compared with 32.4% of people who had annual income less than US\$10 000.¹¹ We found SES was only associated with longitudinal utilization in patients with mild DR, not in initial DFE follow-up, and that patients of the two lower SES brackets had the most DFEs per year. Our findings could be real or due to the fact that we imputed SES using each subject's census tract location and dividing the census tracts for our patients into four quartiles based on relative SES. While this method for estimating SES has been previously validated, it is limited by relying on a patient's address and it cannot differentiate SES of individual people living in the same census tract.

Gender has been significantly associated with different DFE rates in a number of studies, with women consistently having higher rates of eye care compared with men.^{12 14 16} This difference has been attributed to perceived need of care by each gender. According to the Behavioral Risk Factor Surveillance System, 42% of men with moderate-to-severe vision loss reported no need to have an eye examination compared with 29% of women with similar vision loss.²² However, our study found no differences in initial follow-up or eye care utilization between men and women. Our results agree with a recent study from Paskin-Hall *et al*, who also found gender was not significantly associated with annual DFE adherence.²⁴

Distance from a healthcare facility or provider can be a barrier to care. Increased driving distance has been associated with poor glycemic control^{38 39} and lower use of insulin.⁴⁰ One study found that people residing more than 10 miles from a diabetes management center were almost twice as likely to have HbA1C >7% compared with people living closer to the care center.³⁹ In contrast, we only found an association between driving distance and longitudinal utilization in severe patients, with patients living 5–25 miles within our healthcare facility having the most DFEs per year. Patients living within 5 miles of our facility are more likely to be from medically underserved areas than patients living slightly further away. In addition, our population was in an urban area with a large public transportation system. Previous studies linking driving distance to decreased care utilization have been predominantly conducted in rural areas where public transportation is minimal or absent.

Strengths and weaknesses

The strengths of our study include the large urban population followed over 4 years, the ability to determine DFE adherence based on objective data rather than self-report, and the ophthalmology clinical setting, which has not been previously characterized in terms of factors associated with adherence to follow-up eye care.

Weaknesses of our study included limited data concerning self-reported HbA1C levels and ethnicity, although we were able to impute ethnicity using a validated method.²⁷ Another potential weakness is that we were only able to capture DFEs at our clinics. It is possible that some patients received follow-up eye care outside

our clinics that was not captured in our data. Finally, although we attempted to gather extensive patient information, as an observational study, there is a potential for unmeasured confounding of associations.

The results of this study have important clinical and public health implications. Primary care practitioners, diabetic specialists, and eye care providers in urban clinical settings should identify people with diabetes at risk for poor follow-up in order to improve adherence rates, particularly:

- ▶ patients with normal vision;
- ▶ older patients with severe DR;
- ▶ patients with mild DR and no history of other eye diseases;
- ▶ patients with no ophthalmology documented HbA1C or blood glucose;
- ▶ smokers.

Population-based health programs can also target this cohort with specific educational interventions in order to increase eye care utilization among people with diabetes and attenuate the potential for severe visual disability from DR. While all patients with diabetes need to improve follow-up, targeting subgroups with low adherence rates could have a high impact and prevent progression to more severe DR.

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