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Diabetic Retinopathy Disease Burden in Patients With Lower Household Incomes vs Higher Household Incomes

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Abstract

Purpose: To assess the differences in measures of diabetic retinopathy (DR) disease burden between patients in high-income vs low-income ZIP codes when presenting to retina specialists. **Methods:** This retrospective cohort study comprised patients who presented to a retina specialist at Duke Eye Center between 2014 and 2023 for the management of DR. The quartile of patients with the highest income was compared with the quartile with the lowest income. Demographic data included age, sex, and race. Clinical data included glycosylated hemoglobin A_{1c} (HbA_{1c}), visual acuity (VA), DR diagnostic stage, presence of diabetic macular edema (DME) or vitreous hemorrhage, and whether treatment was indicated. Measures of DR disease burden included HbA_{1c}, VA, presence of DME or vitreous hemorrhage, severity of DR, and need for intervention. **Results:** The analysis included 430 eyes of 215 patients. After controlling for age, sex, race, and glycemic control, it was found that patients in the low-income group were more likely to have DME at presentation ($P < .01$), to have more severe DR at presentation ($P < .001$), and to require an intervention for DR ($P < .001$). The VA was worse in the low-income group than in the high-income group (20/50 vs 20/32; $P < .10$); however, this did not reach statistical significance. **Conclusions:** Patients living in low-income ZIP codes have greater DR severity, a higher prevalence of DME, and need for treatment than their high-income counterparts when first presenting to a retina specialist. These findings suggest that patients from low-income backgrounds may face additional barriers before being evaluated by a retina specialist, resulting in more clinically advanced stages of DR at presentation.

Keywords

retina, systemic conditions and the eye, diabetic retinopathy, nonproliferative diabetic retinopathy, proliferative diabetic retinopathy, diabetic macular edema, socioeconomics

Introduction

Diabetic retinopathy (DR) is one of the most common microvascular complications of diabetes mellitus (DM), and its consequences of diabetic macular edema (DME) and vitreous hemorrhage result in vision loss.[1,2] DR is the most common cause of new-onset blindness in adult patients in developed countries and is associated with earlier onset of other ocular diseases, including glaucoma and cataract.[1]

Many factors contribute to the development and progression of DR, the most influential of which is a higher glycosylated hemoglobin A_{1c} (HbA_{1c}) level.[3] However, beyond HbA_{1c} levels, other factors contributing to the development of DR include the duration of diabetes, high body mass index, elevated total cholesterol levels, and poor blood pressure control.[4,5]

The natural history of DR follows a typical course, initially presenting as mild nonproliferative DR (NPDR), which is characterized by microaneurysms. DR then progresses to moderate and severe NPDR, characterized by an increase in microaneurysms, intraretinal hemorrhages, hard exudates, and retinal venous abnormalities, ultimately culminating in proliferative DR (PDR), which is characterized by neovascularization and may lead to vitreous hemorrhage and vision loss.[2] Because vascular permeability can increase in the earliest stages of DR, ME or thickening of the retina caused by leaky blood vessels can occur at any stage of the disease.[2] The mainstay treatment for DR and DME includes intravitreal antivascular endothelial growth factor (anti-VEGF) injections, laser application, and vitrectomy.[6] However, these interventions,

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especially anti-VEGF injections, require frequent follow-up and there are inherent costs associated with these therapies.[6]

Diabetes is a multifaceted disease that requires consistent and routine medical and lifestyle management.[7] Socioeconomic status, physical environment, food availability, healthcare access, and social context all play important roles in diabetes-related outcomes[7,8]; however, the specific role of socioeconomic status on the presentation and progression of DR has not been evaluated.[3]

This retrospective cross-sectional study investigated the influence of socioeconomic status on DR disease burden in patients with type 2 diabetes by assessing the differences in measures of DR disease burden between patients from high-income ZIP codes vs low-income ZIP codes when presenting to retina specialists. DR disease burden was assessed by visual acuity (VA), the presence of vitreous hemorrhage, the presence of DME, the severity of DR, and an immediate need for treatment.

Methods

This retrospective single-center observational study comprised patients diagnosed with type 2 diabetes who were seen by doctors in the retina service of the Duke Eye Center between 2014 and 2023. Approval for this study was obtained from the Duke University Health System Institutional Review Board (Pro00111550). Because inclusion in the study posed no substantial risk to participants and data analysis consisted of de-identified data obtained through retrospective chart review, the requirement of informed consent was waived. This study complied with the US Health Insurance Portability and Accountability Act of 1996 and the tenets of the Declaration of Helsinki.

Patients seen by ophthalmologists in the Duke Eye Center retina service were identified using Clarity (Duke University Health System), a database formed from the clinical information application of the electronic medical record used at Duke Health (Maestro Care). The Clarity database was also used to identify patients diagnosed with type 2 DM with DR from the Duke Health electronic medical record (International Classification of Diseases [ICD] subcodes E11.31, E11.32, E11.33, E11.34, E11.35). Patients with retinal vascular occlusions, macular degeneration, hereditary retinal dystrophy, uveitis, and degenerative myopia (ICD subcodes H34.81, H34.83, H35.321-H35.323, H35.329, H35.5, H44.11, H44.13, H44.2) were excluded.

The Clarity reporting database was used to collect demographic data, including age, sex, race/ethnicity, and ZIP code. Patients were then matched to the US Census Bureau 2020 median household income by ZIP code of residence. When stratified by household income, patients residing in ZIP codes in the top quartile (>75th percentile) of the dataset were categorized as high income, and patients residing in ZIP codes in the bottom quartile (<25th percentile) of the dataset were categorized as low income.

On presentation to a doctor in the retina service of Duke Eye Center, a retrospective chart review of each patient in the high-income group and low-income group was completed. Clinical data included the most recent HbA_{1c} before presentation, VA, DR diagnosis (no retinopathy, mild NPDR, moderate NPDR, severe NPDR, PDR), DME (no DME, presence of DME), vitreous hemorrhage (no vitreous hemorrhage, presence of vitreous hemorrhage), and the need for treatment at the baseline examination and the most recent follow-up (ie, whether anti-VEGF injections, laser treatments, or pars plana vitrectomy were performed within 2 months of presentation). Patients with miscoded type 1 diabetes and those who did not see an ophthalmologist in the Duke Eye Center retina service for DR were excluded from the dataset.

All statistical analyses were completed with SAS software (version 9.4, SAS Institute Inc). The 2 groups were compared by a statistician (S.S.S.) using multivariable generalized estimating equations (GEEs) that accounted for the inclusion of 2 eyes from the same patient. Patient-level demographic and clinical variables were compared across the groups using the Wilcoxon rank sum test for continuous variables and Fisher exact test for categorical variables. DR outcomes were compared at the eye level across the groups using a Z test of the difference in means between groups, with GEEs for continuous variables, a test of the difference in proportions between the groups using GEEs with a logit link for dichotomous variables, and a test of the difference in proportions between the groups using GEEs with a multinomial link for 3-level variables. Statistical significance was set at $P < .05$.

Results

The analysis included 430 eyes of 215 patients. The high-income group comprised 196 eyes of 98 patients and the low-income group, 234 eyes of 117 patients. Table 1 shows the demographic information. The mean age of the patients was 68.3 years and 65.3 years, respectively ($P < .05$).

In the high-income group, the highest percentage of patients were White followed by Black, Asian, and other/unknown. In the low-income group, the highest percentage of patients were Black followed by White, other/unknown, and Asian. The difference between groups was statistically significant ($P < .001$) (Table 1).

The mean household income was $100,839.80 in the high-income group and $47,908.60 in the low-income group. The difference between groups was statistically significant ($P < .001$).

Differences were found in the stage of DR at presentation between the high-income and low-income groups (Figure 1). In the high-income group, 32.1% of eyes had mild NPDR, while only 9.4% of eyes in the low-income group had mild NPDR. The percentage of eyes with moderate NPDR was similar between the groups. However, severe NPDR was almost twice as common in the low-income group than in the high-income group (23.9% vs 12.8%). Similarly, PDR was more than twice as common in the low-income group than in the high-income group (31.2% vs 14.3%). Overall, the distribution of DR severity was significantly different between the low-income group and high-income group, with more severe DR seen in the low-income group at presentation ($P < .001$).

Table 1. Demographics.

Variable	High Income (n = 98)	Low Income (n = 117)	*P* Value[a]
Age (y)			.020[c]
Mean ± SD	68.3 ± 11.6	65.3 ± 11.1	
Median	31	32	
Min, max	71, 88	68, 86	
Race, n (%)			< .001[c]
Asian	13 (13.3)	1 (0.8)	
Black	27 (27.5)	70 (59.8)	
White	52 (53.1)	43 (36.7)	
Other/unknown	6 (6.1)	3 (2.6)	
Sex, n (%)			.054[c]
Male	53 (54.1)	47 (40.2)	
Female	45 (45.9)	70 (59.8)	
Income (US$)			< .001[c]
Mean ± SD	100,839.80 ± 18,234.10	47,908.60 ± 4449.30	
Median	81,028	32,882	
Min, max	98,049, 136,019	50,631, 53,194	
HbA_{1c}[b] (%)			.002[c]
Mean ± SD	8.0 ± 2.0	8.9 ± 2.3	
Median	5.3	5.0	
Min, max	7.2, 14.0	8.4, 14.5	

Abbreviation: HbA_{1c}, glycosylated hemoglobin A_{1c}.
[a]*P* values for race and sex based on Fisher exact test; *P* values for age, income, and HbA_{1c} based on Wilcoxon rank sum test.
[b]High-income group, n = 98; low-income group, n = 116.
[c]Statistically significant.

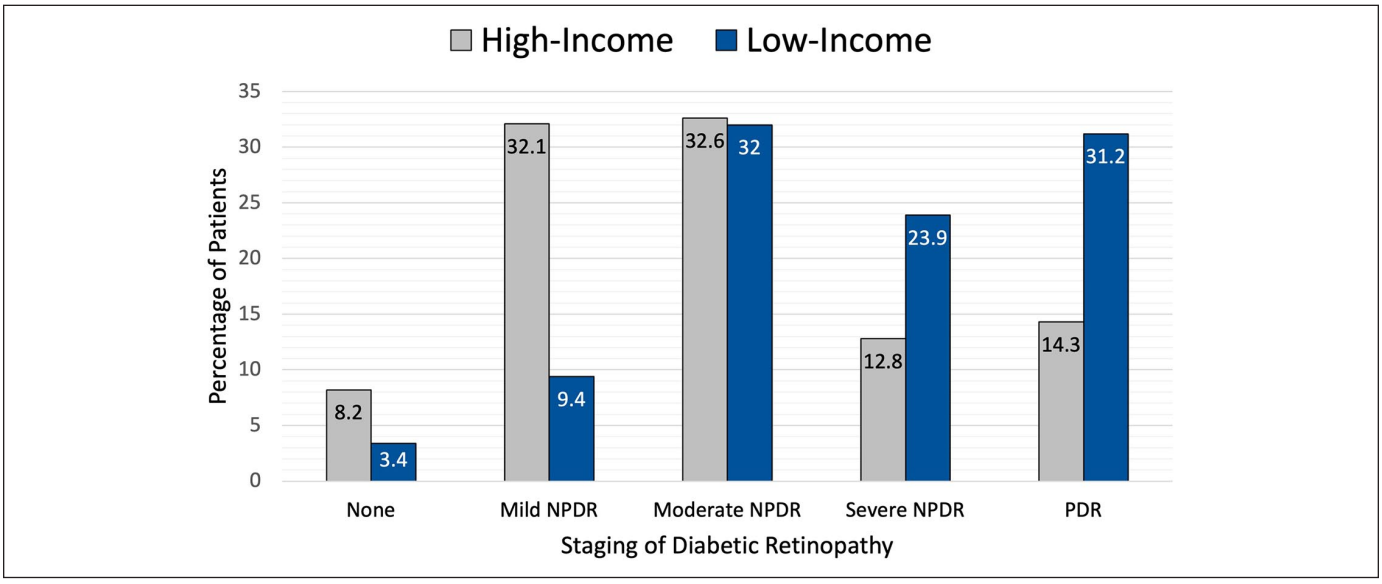

Figure 1. Diabetic retinopathy staging in the high-income group and low-income group.
Abbreviations: NPDR, nonproliferative diabetic retinopathy; PDR, proliferative diabetic retinopathy.

Furthermore, 77.3% of eyes in the low-income group had DME at presentation while only 56.6% of eyes in the high-income group had DME ($P = .001$). Eyes of patients in the low-income group were also more than twice as likely to require an intervention for DR (33.3% vs 15.3%) ($P < .001$). The VA was worse in the low-income group (20/50 vs 20/32) ($P = .011$); however, this did not reach statistical significance when adjusting for demographic differences between the groups ($P = .072$).

Table 2. Outcomes.

Outcome	High Income (n = 196)	Low Income (n = 234)	*P* Value		
			Unadjusted[a]	Adjusted[b]	Adjusted[c]
LogMAR visual acuity					
Mean ± SD	0.23 ± 0.40	0.36 ± 0.44	.011[d]	.072	.069
Median	0.0	0.0			
Min, Max	0.1, 2.6	0.2, 2.3			
Macular edema, n (%)	111 (56.6)	181 (77.3)	.001[d]	.004[d]	.005[d]
Vitreous hemorrhage, n (%)	5 (2.6)	25 (10.7)	.010[d]	—	—
Type of DR, n (%)			< .001[d]	< .001[d]	< .001[d]
None	16 (8.2)	8 (3.4)			
Mild nonproliferative	63 (32.1)	22 (9.4)			
Moderate nonproliferative	64 (32.6)	75 (32.0)			
Severe nonproliferative	25 (12.8)	56 (23.9)			
Proliferative	28 (14.3)	73 (31.2)			
Intervention performed, n (%)	30 (15.3)	78 (33.3)	< .001[d]	.001[d]	< .001[d]

Abbreviations: DR, diabetic retinopathy; HbA_{1c}, glycosylated hemoglobin A_{1c}.
[a]*P* value for binary variables based on difference between proportions with binomial logistic regression calculated with generalized estimating equations (GEEs) to account for including both eyes of patients. *P* value for type of DR based on difference between proportions with multinomial logistic regression calculated with GEEs to account for including both eyes of patients. *P* value for continuous variables based on difference between means using GEEs to account for inclusion of both eyes of patients.
[b]Adjusted *P* values are computed similarly while adjusting for age, sex, and race.
[c]Adjusted *P* values are computed similarly while adjusting for age, sex, and race and HbA_{1c}.
[d]Statistically significant.

Because there were statistically significant differences in race, age, and sex between the 2 groups, these factors were controlled for in the DR outcome analyses with adjusted *P* values (Table 2, column 5). After controlling for race, age, and sex, there was no significant difference in VA between low-income patients and high-income patients ($P = .072$). However, patients in the low-income group had significantly higher rates of DME ($P = .004$), had more severe DR ($P < .001$), and were more likely to need an intervention ($P = .001$).

Because the HbA_{1c} was significantly different between the 2 groups, a secondary analysis was completed, with adjusted *P* values for differences in DR outcomes when controlling for age, sex, race, and HbA_{1c} (Table 2, column 6). After controlling for race, age, sex, and HbA_{1c}, there was no significant difference in VA between low-income patients and high-income patients ($P = .069$). However, patients in the low-income group had significantly higher rates of DME ($P = .005$), had more severe DR ($P < .001$), and were more likely to need an intervention ($P < .001$).

Conclusions

Social conditions fundamentally drive health inequality,[9] and understanding how the socioeconomic status of patients specifically manifests in differential DR outcomes is crucial to improving outcomes. Our study found that patients living in lower-income ZIP codes present to a retina clinic with a significantly higher burden of DR, as evidenced by significantly higher rates of DME, more severe DR, and a higher treatment burden at presentation after controlling for age, sex, and race.

The HbA_{1c} levels were significantly different between the 2 groups, and we found that even when also controlling for HbA_{1c}, the DR burden was significantly higher in the low-income group. This suggests that although differences in HbA_{1c} may have contributed to the differences in DR burden between the 2 groups, it does not fully account for why low-income patients had a higher DR burden. HbA_{1c} is the diagnostic test of choice for diabetes; however, it has shortcomings when used as a proxy for diabetes severity.[10] Specifically, HbA_{1c} levels do not provide insight into the daily variability in blood glucose concentrations or the duration of a patient's untreated diabetes.[10] Patients from lower income backgrounds face barriers in the care of their type 2 diabetes[7] that may lead to suboptimal control of their disease and contribute to worsening of DR progression.

An important finding in our analysis is that there was no statistically significant difference in VA between the 2 groups, although there was a trend toward statistical significance. DR in its early stages is asymptomatic,[11] and patients may not notice changes in their vision until their retinopathy progresses to more symptomatic stages. Patients from more disadvantaged socioeconomic backgrounds have a lower probability of visiting specialist physicians[12] and may be even less likely to do so when they are under the impression that their health is not in jeopardy. Patients living with DR face numerous barriers to care, including having multiple other medical appointments, cost, and a lack of perceived changes in VA.[13] These barriers may make the management of asymptomatic DR less of a priority for low-income patients until their vision begins to deteriorate. Because DR is a silently progressing disease, it is critical to not only emphasize the importance of routine ophthalmology

visits but also to reduce structural barriers to care for patients from low-income backgrounds who are living with DR.

Beyond cost barriers and a lack of changes in vision, understanding the mechanisms through which socioeconomic status influences DR severity is crucial to address the obstacles that lead to worse vision outcomes. Lower educational attainment has been found to be a strong risk factor for DR.[14,15] Patients may have less of an understanding of their DR diagnosis, exacerbating already existing disparities in care. Furthermore, low-income patients may have less access to newer, more potent antihyperglycemic agents. Glucagon-like peptide-1 receptor agonists and sodium-glucose cotransporter-2 inhibitors are recommended therapies for more than 80% of US adults with type 2 diabetes[16,17]; however, these therapeutics are less likely to be initiated in patients from low socioeconomic backgrounds because of the higher costs.[18,19]

In addition to access to medication and education, transportation barriers, including a lack of available transport, disproportionately affect patients from lower income backgrounds and those who live with chronic disease.[20] This specifically manifests in patients with DR, whose disease requires frequent follow-ups with a retina specialist to monitor disease progression and the need for treatment. Transportation, or lack thereof, not only serves as an obstacle for the initial appointment, even if a referral were placed, but it also may delay long-term follow-up.

Contrary to our findings, previous research has found that socioeconomic status may not be associated with DR progression[15]; however, most analyses are limited to international or ethnically small cohorts of patients or only patients with type 1 diabetes. In a cohort of Australian adults followed over 5 years, DR progression was not associated with socioeconomic status or education.[21] In addition, Mexican Americans' lower socioeconomic status was not associated with greater levels of hyperglycemia or staging of DR.[22] However, other studies in British and Japanese populations found that higher socioeconomic status was negatively associated with the development of retinopathy.[23,24] One study found that in patients with type 1 diabetes, lower socioeconomic status was a risk factor for the development of DR, independent of glycemic control.[25]

Our study is novel in that it compared DR severity between high-income patients and low-income patients at their time of presentation to a retina specialist, a pivotal timepoint for interventions to optimize vision and emphasize DR management. To our knowledge, ours is the first study to find that the DR burden is significantly higher in low-income patients independent of age, sex, race, and HbA_{1c}, as evidenced by significantly higher rates of DME, more severe DR, and a higher treatment burden. Our study is also unique in that it includes a racially diverse cohort of patients with type 2 diabetes, which disproportionately affects patients from low-income backgrounds.[7]

Our study has limitations. By using a cross-sectional approach, we did not follow patients over time and analyze how the development and progression of DR are influenced by socioeconomic status. There were 24 eyes of patients without DR at presentation; however, the patients had DR in their fellow eye or were referred out of caution and may have eventually developed DR. A longitudinal analysis is needed to understand at which timepoints patients are most at risk for developing DR so that interventions can be tailored to prevent the development of DR.

In addition, ZIP code–level data were used because individual patient-level socioeconomic status data were unavailable. As such, patients may have higher or lower median incomes than the median income in their ZIP code. ZIP code–level median household income is a validated and preferred measure of area-based socioeconomic status.[26] Future studies that use the Area Deprivation Index would provide patients with more specific insight into neighborhood-level socioeconomic conditions.[27]

Another study limitation is the inclusion of patients at a single site. This limits the generalizability of our findings to other areas of the US and internationally, and further research including multiple sites is warranted.

In conclusion, this retrospective cross-sectional study found that patients in low-income ZIP codes have significantly higher rates of DME, more severe DR, and a higher treatment burden at presentation to a retina specialist than patients in high-income ZIP codes. Patients from low-income backgrounds face barriers to receiving care from retina specialists, including a lack of patient education, delays in care, and limited access to healthcare resources. These barriers can result in worse visual outcomes in low-income patients, requiring costly interventions to reduce the risk for further vision loss. This socioeconomic disparity exacerbates already existing health inequalities. Future research should include longitudinal data and data from multiple sites to better characterize the mediating factors associated with a higher DR burden in patients from lower socioeconomic backgrounds.

Ethical Approval

Ethical approval for this study was obtained from the Duke University Health System IRB (Pro00111550). This study complied with the US Health Insurance Portability and Accountability Act of 1996 and the tenets of the Declaration of Helsinki.

Statement of Informed Consent

Informed consent was waived for the present study because inclusion in the study posed no substantial risk to participants and data analysis consisted of de-identified data obtained through retrospective chart review.

Declaration of Conflicts of Interest

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