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ORIGINAL RESEARCH

High Prevalence of Diabetic Retinopathy in an Outpatient Podiatry Clinic and Associated Barriers to Ophthalmic Care

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Background: Diabetic retinopathy (DR) is a leading cause of vision loss among working-age adults. However, the prevalence of DR among patients with diabetic foot disease—a signal of advanced systemic diabetes complications—is underexplored. Additionally, the substantial comorbidity burden associated with diabetic foot disease may result in a higher incidence of or distinct barriers to ophthalmic care, including structural (access to healthcare), behavioral (prioritization of care), and economic (cost of care) factors, compounding risk of vision loss. This study assesses the prevalence of DR in a podiatric clinic while also investigating participant-reported barriers to routine ophthalmic follow-up.

Methods: We conducted a cross-sectional study that included patients age ≥18 (n=62) receiving diabetic foot care at an outpatient podiatric clinic in 2021 and 2022. DR status was determined through point-of-care digital retinal images or prior DR diagnosis documented in the electronic medical record. Retinal images were interpreted remotely by a board-certified ophthalmologist. Self-reported barriers to regular ophthalmic care were recorded among participants who were lost to follow-up ophthalmic care. Participants were also surveyed for favorable incentives to promote ophthalmic follow-up.

Results: Our findings revealed a high prevalence of DR, with 32 (54%) participants diagnosed with DR and 10 (17%) participants having sight-threatening DR. Notably, 17 (29%) participants were newly diagnosed with DR as a direct result of this study. Of the 62 participants enrolled, 29 (47%) were lost to ophthalmic care. All of these participations reported one or more barriers to receiving ophthalmic care, predominantly related to competing social, economic, and medical challenges, with ophthalmic care being chronically underprioritized. Financial incentives were most favored by participants as an effective means to promote ophthalmic follow-up.

Conclusion: The high prevalence of DR, especially undiagnosed DR, in conjunction with significant barriers to ophthalmic care highlights a critical need for improved screening in outpatient podiatric settings. Integrating digital fundus cameras into outpatient podiatric clinic workflow may enhance DR detection and prevent vision loss in this high-risk population. Addressing identified barriers to routine ophthalmic care may further improve the rate of follow-up care and reduce the burden of DR-related vision loss among patients with diabetic foot disease.

Keywords: diabetic retinopathy, retinal screening, digital retinal imaging, diabetic foot disease

Background

Diabetic retinopathy (DR) is the leading cause of vision loss in working-age adults,[1] affecting approximately 103 million individuals worldwide.[2] With 1.4 million new diabetes diagnoses each year,[3] the prevalence of DR is expected to rise precipitously in the coming decades. Early DR diagnosis prevents the majority of DR complications,[4] yet up to half of patients with diabetes in the US do not receive recommended ophthalmic follow-up.[5,6] Thus, it is becoming increasingly

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important to identify high-risk diabetic patient populations for targeted DR screening and to develop innovative strategies to effectively screen large populations.[7,8]

Diabetic foot disease results from longstanding diabetes-related damage in multiple organ systems, leading to vascular compromise, immune system dysfunction, and peripheral nerve damage.[9–11] Consequently, diabetes-related podiatric conditions such as non-healing foot ulcer, osteomyelitis, and Charcot arthropathy represent late-stage diabetes complications.[12] Previous studies have observed an association between DR and diabetes-related podiatric disease;[13–17] however, the prevalence of DR and barriers to regular ophthalmic follow-up remain unexplored in the outpatient podiatric population. Given that patients seeking diabetic podiatry care exhibit signs of diabetes-related end-organ damage, we hypothesized that this population would be at heightened risk for DR, and DR prevalence would surpass the range of 21–31% reported in the literature.[18] Furthermore, the substantial comorbidity burden associated with diabetic foot disease has been shown to result in particularly high healthcare utilization, comparable to or exceeding rates observed in cancer and congestive heart failure.[19–21] We further hypothesized that this high comorbidity burden contributes to inadequate ophthalmic follow-up and a higher prevalence of undiagnosed DR among these patients. Understanding DR prevalence, undiagnosed DR occurrence, and barriers to routine eye care experienced by this population is crucial for developing targeted strategies to enhance DR screening and management in the podiatric patient population.

The purpose of this study was to assess the prevalence of DR and undiagnosed DR at a single outpatient podiatric clinic using point-of-care digital fundus photography combined with electronic medical record review. Additionally, the study seeks to identify barriers that preclude regular ophthalmic care in this patient population and comment on incentive preferences to improve follow-up nonadherence. By addressing these gaps, we intend to provide insights into the unmet ophthalmic needs of the podiatric population, which may inform the development of targeted screening programs to reduce vision loss burden in high-risk diabetic patients.

Research Design and Methods

This study was carried out with approval from the University of Pittsburgh Institutional Review Board (STUDY21010002) and adhered to the tenets of the Declaration of Helsinki. All participants provided informed consent to participate in the study. Participant confidentiality was maintained in accordance with Health Insurance Portability and Accessibility Act (HIPAA) compliance.

Recruitment Methods

This cross-sectional study was conducted at a single outpatient podiatric clinic affiliated with a large academic institution. Patient enrollment occurred over 16.5 clinic days in 2021 and 2022. Eligible patients were identified by study team members and approached by a member of the clinical care staff to gauge initial interest in participating. Approximately 500 patients were deemed eligible to participate. IRB protocols at our institution require that patients were approached by podiatry clinical staff to verbally consent to study participation before being approached by the research team. This barrier substantially reduced the number of patients included. Inclusion criteria included men and women age 18 or older with a known diagnosis of type 1 or type 2 diabetes mellitus who were receiving diabetic foot care at the UPMC Comprehensive Foot and Ankle Center. Patients were excluded if they had been diagnosed with type 1 diabetes within the past 5 years, as they were unlikely to have developed diabetic retinopathy within that timeframe. Participants with a documented history of diabetic retinopathy, or who had an ophthalmic exam within the past year showing no signs of retinopathy, were offered the choice to participate in both retinal imaging and a barriers-to-care survey or in the survey alone. Those without a documented history of retinopathy or a recent ophthalmic exam were enrolled to undergo both retinal imaging and the barriers-to-care survey. All participants were informed of potential risks and provided consent before participating in the study.

Retinal Imaging

Participants who elected to undergo retinal imaging were taken to an examination room where 45-degree, single-field digital fundus photographs were captured using a CenterVue Digital Retinal System camera. If a participant's

pupils were too small for quality images, one drop of 0.5% tropicamide was administered to each eye for pupillary dilation. Retinal images were assessed for retinopathy and interpreted as having no retinopathy, mild nonproliferative diabetic retinopathy (NPDR), moderate NDPR, severe NPDR, or PDR.[22] Vision-threatening retinopathy was defined as severe NPDR or PDR with or without macular edema.[23] Data from participants whose fundus images were not gradable due to image quality were excluded from DR prevalence analysis. Images were interpreted remotely by a board-certified ophthalmologist who was blinded to the participants' medical histories. Participants diagnosed with DR were contacted by research staff, informed of their diagnosis and advised to complete a formal eye exam.

Demographic and Medical Data

An investigator-administered questionnaire and electronic medical record review were utilized to record participant demographic and medical data. The following demographic information was collected: age, gender, health insurance status and type, marital status, and highest level of education completed. Insurance was categorized as Medicaid, Medicare, or Commercial for the purposes of our analyses. The electronic health record was searched for the following data: previous diagnosis of retinopathy, diabetes mellitus (DM)-controlling medications, number of recent hospitalizations within the past year, number of recent doctor visits within the past year, A1C, hypertension, coronary artery disease, chronic kidney disease, neuropathy, and peripheral vascular disease.

Assessment of Participant Barriers to Care and Favorable Incentives to Promote Follow-up

An investigator-administered survey was conducted to identify barriers to care and preferred incentives to promote follow-up. Survey questions were adapted from a prior study documenting the prevalence of DR, barriers to regular ophthalmic care, and acceptance of screening interventions among patients with diabetes in an emergency department setting.[24] Fifteen questions were selected to reliably capture barriers to ophthalmic care among individuals who had not received a dilated eye examination in the past 12 months. These questions addressed general healthcare access (access to a primary care physician, ophthalmologist, endocrinologist, and other specialists), health insurance status, and structural, behavioral, and economic barriers to ophthalmic care. Participants were asked to report all relevant barriers and identify the single most significant barrier out of 11 predefined options, with an "Other" category included. Seven questions were included to assess favorable structural, behavioral, and economic incentives to encourage ophthalmic follow-up and to compare findings with those of the earlier study.[25] All participants were asked to rate, on a scale of 1-to-10 the appeal of various behavioral economic approaches to encourage regular ophthalmic follow-up.

Results

Prevalence of Diabetic Retinopathy Within an Outpatient Podiatric Population

Sixty-two patients with diabetes mellitus (DM) who presented for podiatric care were recruited in this study. The average participant age was 61.7 ± 12.0 years (Table 1). Forty-one (66%) of participants identified as male, and 21 (34%) identified as female. Twenty-two (36%) participants had Medicaid, 23 (37%) had Medicare, and 15 (24%) had commercial insurance.

Sixty-one (98%) participants had type II diabetes, with a mean A1c of 8.23 ± 2.13 mmol/L (Table 2). Notably, 32 (54%) participants were diagnosed with DR, with the majority (27, 84%) having NPDR and 5 (16%) individuals having PDR (Table 3). Among those with NPDR, 11 (41%) had mild disease without exudate, 11 (41%) had moderate disease, and 5 (19%) had severe disease. Importantly, 17 (29%) participants were newly diagnosed with DR through this study, all of which had NPDR. Individuals who were newly diagnosed with DR reported a shorter duration of DM than those with a known diagnosis. The average duration of DM was 15 years (95% CI: 3.9) for newly diagnosed participants and 21 years (95% CI: 5.7) for previously diagnosed participants.

Table 1 Participant Demographics

Characteristic	**n (%)**
Age (mean ± standard deviation) in years	61.7 ± 12.0
Gender	
Male	41 (66%)
Female	21 (34%)
Education	
Did not complete high school	5 (8%)
High school	26 (42%)
Associates degree/Some college	9 (15%)
Bachelor's degree	15 (25%)
Graduate degree	5 (8%)
Employment status	
Unemployed/disability	16 (26%)
Part-time	3 (5%)
Full-time	16 (26%)
Retired	25 (40%)
Marital status	
Single	27 (44%)
Married	23 (37%)
Divorced/Widowed	10 (16%)
Insurance status	
Medicaid	22 (36%)
Medicare	23 (37%)
Commercial	15 (24%)

Table 2 Health Information

Characteristic	**n (%)**
Type II diabetes	61 (98%)
Average A_1C in mmol/L (mean ± standard deviation)	8.23 ± 2.13
Hypertension	54 (87%)
Coronary artery disease	13 (21%)
Renal disease	15 (24%)
Neuropathy/Peripheral vascular disease	54 (87%)
Tobacco use (past or present)	30 (48%)

(*Continued*)

Table 2 (Continued).

Characteristic	n (%)
Has an eye doctor	45 (73%)
Has a PCP	59 (95%)
Has seen PCP within past year	55 (89%)
Average number of doctor visits within past year (mean ± standard deviation)	13.88 ± 8.56
Average number of hospitalizations within past year (mean ± standard deviation)	2.22 ± 2.19

Table 3 Prevalence of NPDR and PDR in Study Population

Diabetic Retinopathy Diagnosis	n Diagnosed/Population n (%)
Diagnosis of diabetic retinopathy (any)	32/59 (54%)
Non-proliferative DR	27/32 (84%)
Mild NPDR	11/27 (41%)
Moderate NPDR	11/27 (41%)
Severe NPDR	5/27 (19%)
Proliferative DR	5/32 (16%)
Previously undiagnosed DR (any)	17/59 (29%)
Mild NPDR	6/17 (35%)
Moderate NPDR	7/17 (41%)
Severe NPDR	4/17 (24%)

Barriers to Routine Ophthalmic Care Within an Outpatient Podiatric Population

Fifty-nine (95%) survey respondents reported previous awareness that diabetes could affect their eyes. Twenty-nine (47%) participants had not received a dilated eye exam in the year prior to enrollment and were surveyed for perceived barriers to regular ophthalmic care. All 29 participants lost to ophthalmic care reported one or more barriers to ophthalmic care. "Other" was the most common selected reason, being chosen 11 times overall and 8 times as the most significant barrier (Figure 1). Individuals who selected "Other" cited life stressors such as competing medical needs (36%), work (18%), interpersonal obligations (9%), cost (9%), and unique, extenuating circumstances outside of the participant's control (27%). Outside of the "Other" response, frequently reported barriers to care included "fine" visual perception, examination cost, being too busy, and having too many other medical appointments.

Behavioral Incentives to Promote Follow-up Ophthalmic Care in a High-Risk Population

Given the high prevalence of DR, particularly undiagnosed DR, we explored incentives that may promote ophthalmic follow-up care. Financial incentives were the most favored, with 32 (52%) participants endorsing a $10 voucher or a 1-in-100 chance to win $1000 following appointment attendance as the most effective strategies (Table 4).

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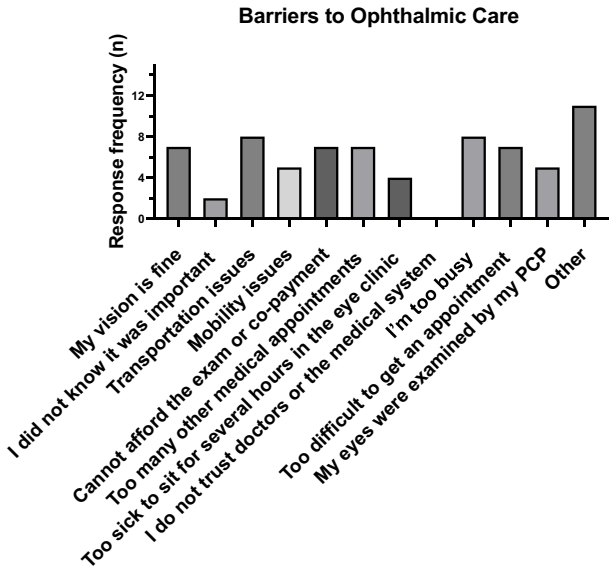

Figure 1 Barriers to routine ophthalmic care. All perceived barriers to routine ophthalmic care reported by 29 participants who had not received a dilated eye exam at least one year prior to enrollment; participants could list more than one barrier if applicable.

Discussion

This study highlights a heightened prevalence of DR within an outpatient podiatry clinic, suggesting that this population may be at higher risk for DR. Our findings, consistent with previous reports,[13–17] suggest a high rate of retinopathy in individuals who present for diabetic foot care, with half of our participants diagnosed with DR and nearly one-third of the study population newly diagnosed as a direct result of this study. Our data underscore the importance of identifying high-risk groups and designing DR screening paradigms accordingly.

The high rate of moderate NPDR among newly diagnosed participants highlights a critical opportunity to intervene before progression to severe NPDR or PDR occurs. This underscores the utility of telemedicine to detect DR cases and urges the placement of fundus cameras in high-risk areas, including podiatry clinics.

Barriers to ophthalmic care remain a significant challenge, as reflected in our survey results. Nearly all participants reported having a primary care physician, suggesting a baseline willingness to engage with the healthcare system, and a previous awareness that diabetes could affect their eyes. However, nearly half of participants did not receive an eye exam in the last year; thus, healthcare engagement and awareness alone do not translate to consistent follow-up. One explanation for this observation is that many participants could not prioritize eye care due to other healthcare needs and

Table 4 Participant-Reported Behavioral Incentives to Promote Ophthalmic Follow-up

Preferred Incentive for Follow-Up	Response Frequency n (%)
Financial incentive in the form of a $10 voucher	17 (27)
Financial incentive in the form of a 1-in-100 chance to win a voucher for $1000	15 (24)
Access to a reliable shuttle system to/from the ophthalmologist's office	9 (15)
Text message reminders	7 (11)
Eye appointment scheduled for you	7 (11)
Phone call reminders	3 (5)
Declined to comment	3 (5)
Disliked all options	1 (2)

barriers to care. These interpretations were qualitatively verified by survey responses, wherein participants most frequently cited "finances", "being too busy with other things", and "having too many other medical appointments" as reasons for not seeking eye care. Similarly, Williams et al2022, examined barriers to ophthalmic care in patients with diabetes presenting to an emergency department for acute care and found that the majority of participants reported having too many other medical appointments, being too busy, or difficulty affording the exam.[24] Accordingly, the addition of screening methodologies which are convenient and accessible is of paramount importance in the prevention of vision loss in these populations, highlighting the utility of point-of-care DR screening modalities for high-risk patients.

An essential component of improving ophthalmic care engagement in conjunction with early screening is comprehensive diabetes and DR education facilitated by the care team. While early screenings can prevent DR complications,[4] patient-education is a critical adjunct. Patient-tailored education on the development of DR, DR-related complications, and the importance of regular follow-up to preserve vision results in improved ophthalmic follow-up adherence and increased patient satisfaction.[25–27] This education should be reinforced by the entire care team to ensure patient understanding. Thus, improving follow-up adherence among patients with DM should include a multifaceted approach that integrates DR screening with regular, patient-specific, provider-led DR education.

While screening and patient education may promote early and regular ophthalmic follow-up, financial incentives may further encourage DR follow-up in populations where economic barriers persist. Financial incentives have emerged as a potential strategy to encourage follow-up ophthalmic care among the podiatric population studied. Over half (52%) of participants preferred financial incentives, in the form of either a $10 voucher or a 1-in-100 chance to win $1000, to increase follow-up. This preference may reflect the demographic makeup of this population, with over a third of participants meeting financial qualifications for Medicaid insurance. Interestingly, one UK study of similar financial incentives (£10 or a lottery for £1000) found these patients were less likely to attend their appointments than the control group with no incentive.[28] Additional research is needed to validate the efficacy of financial incentives within this specific population.

Our study has several limitations. Our focus on a single clinic limits the generalizability to outpatient clinics in other specialties. Barriers to care and incentive preferences may also differ in podiatry clinics in other geographic locations with varying social safety net programs. Further, we did not assess participants' DR-related fund of knowledge or social support structure which may further affect ophthalmic care access and follow-up adherence. In addition, patient participation in this study was suboptimal. Podiatric staff related that some patients refused to participate due to time constraints. IRB requirements stipulated clinic staff needed to make first contact with eligible participants and inquire about participation. This appears to have been the most common reason for the lack of enrollment. As such, our results may underestimate the true prevalence of DR in this population, as individuals not wanting to participate may have been aware of their DR diagnosis and did not want to dedicate additional time to screening. Other nonparticipants may chronically under-prioritize ophthalmic care and be at high risk for undiagnosed DR. To address low participation uptake, our study design included an option to opt out of digital fundus photography, thus reducing participation time, for individuals who screened negative within the past 364 days or those with a documented history of DR. While this practice aligns with the AAO's Preferred Practice Pattern for repeat DR screening following a negative examination,[29] it is possible that some participants may have developed DR between their negative screen and study participation, constituting a false negative in our overall prevalence. Six individuals with a recent negative exam were classified as "negative DR" for the purpose of this study. Estimations of DR prevalence in this population would be most accurate if screening were incorporated into a routine part of podiatric visits. Nevertheless, while the number of patients included is smaller than the total eligible and smaller than we would have liked, the sample size is large enough to clearly demonstrate a prevalence of retinopathy, undiagnosed retinopathy and vision threatening retinopathy in excess of what a comprehensive ophthalmologist would expect to see while screening diabetic patients during annual exams.

Conclusions

This study conducted targeted DR screening in a high-risk patient population, characterized by a heightened likelihood of DM-mediated end-organ damage and distinct barriers to routine ophthalmic care. Targeted screening identified a significant prevalence of DR, as well as previously undiagnosed DR, in conjunction with substantial barriers to

ophthalmic care, underscoring the value of integrating DR screening into outpatient podiatric clinics. The placement of fundus cameras in these settings and incorporation of screening into routine clinic workflows is likely to improve patient engagement and prevent unnecessary vision loss within a high-risk population. Further research is needed to generalize DR prevalence across multiple podiatric sites, validate the efficacy of screening when incorporated into the clinical workflow, and optimize implementation strategies.

Ethics Approval and Consent to Participate

This study was carried out with approval from the University of Pittsburgh Institutional Review Board (STUDY21010002). All participants provided informed consent to participate in the study.

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Disclosure

All authors declare that they have no competing interests for this work.

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