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Impact of teleretinal screening program on diabetic retinopathy screening compliance rates in community health centers: a quasi-experimental study

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Abstract

Background Diabetic retinopathy (DR) remains a leading cause of preventable blindness, with inadequate screening rates even in urban areas with high concentrations of medical professionals. While medical guidelines recommend annual diabetic retinopathy screening for patients with diabetes mellitus, adherence to these recommendations remains low. This study evaluates the impact of a novel teleretinal DR screening program on screening compliance across urban community health centers in Boston, Massachusetts.

Methods We conducted a quasi-experimental study comparing DR screening compliance between intervention and comparison community health centers before and after implementing a teleretinal screening program. Participants included patients diagnosed with diabetes mellitus with primary care providers at the studied sites. We defined compliance as completion of either teleretinal screening or a documented eye care professional examination within the previous 365 days. Monthly compliance rates were analyzed using two-way fixed effects regression and event study techniques.

Results The study included 10,247 patients with diabetes mellitus who received care at six participating sites, generating 222 monthly compliance rate estimates. Baseline compliance rates before implementation ranged from 25 to 40% across sites. The two-way fixed effects regression analysis revealed that the screening program significantly increased DR compliance rates by an average of 7.2% points ($p < 0.001$). Event study analysis showed positive effects across all sites, though the initial improvement tended to diminish over time.

Conclusions Implementation of a community-based teleretinal DR screening program significantly improved compliance with annual screening guidelines in urban communities. These findings support the broader adoption of teleretinal screening as an effective strategy for preventing DR-related vision loss in vulnerable populations. Further research is needed to assess long-term clinical outcomes and optimize program sustainability.

Keywords Diabetic retinopathy, Screening, Telemedicine, Diabetes mellitus, Primary care

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Contributions to the literature

- Research on the use of teleretinal screening for diabetic retinopathy (DR) is limited in urban settings with high concentrations of medical providers.
- This study demonstrates the effectiveness of a primary-care based teleretinal screening program in improving compliance with DR screening recommendations in community health centers within one of the largest health systems in the state of Massachusetts.
- The modest effect size suggests persisting barriers even in areas with high healthcare accessibility, such as competing priorities in primary care and resource limitations for support staff.

Background

Diabetic retinopathy (DR) is a leading cause of preventable blindness among working-aged adults worldwide, affecting approximately one third of individuals with diabetes mellitus (DM) [1]. The global prevalence of DR is projected to increase dramatically in the coming years, paralleling the rising incidence of diabetes [2]. A particularly concerning aspect of DR is its ability to progress silently, often remaining asymptomatic even in advanced stages, underscoring the importance of regular screening for early detection and timely intervention.

Current guidelines from major health organizations emphasize the need for regular retinal examinations in patients with DM. The American Academy of Ophthalmology recommends annual dilated retinal examinations starting five years after diagnosis for those with type 1 diabetes, or at the time of diagnosis for those with type 2 diabetes [3]. Similarly, the American Diabetes Association suggests annual exams, with the possibility of extending to biennial exams for patients without evidence of retinopathy on one or more annual screenings [4]. Despite these recommendations, adherence to screening guidelines remains low, with only about 60% of people with diabetes receiving the minimum recommended examinations [3]. This is especially concerning given that timely treatment for DR is crucial in preventing severe vision loss [5]. The consequences of untreated DR can be severe, ranging from neovascular glaucoma to tractional retinal detachment and vitreous hemorrhage, ultimately leading to substantial visual impairment. Therefore, the development of effective screening processes is critical for detecting patients requiring referral to an ophthalmologist for comprehensive examination and treatment.

Teleretinal screening has emerged as a promising solution to enhance the accessibility, efficiency, and cost-effectiveness of DR evaluation for the growing diabetic population [6]. In standard teleretinal screening, fundus photos are captured in the primary care setting and then evaluated remotely by ophthalmologists. Patients requiring further examination are subsequently referred for comprehensive evaluation [7–10]. Various imaging modalities, including multifield and wide-field non-mydriatic photography, have been utilized in the context of teleretinal screening, each offering unique advantages in image quality and ease of use [11–13].

While the majority of teleretinal screening studies have focused on rural or international settings where physical distance from ophthalmic care centers is the primary barrier to access, there is increasing recognition that similar challenges exist in urban communities geographically proximate to ophthalmic centers [14, 15]. In these urban settings, patients may face other barriers such as lack of transportation, inability to take time off work, childcare responsibilities, or limited health literacy [16–19]. Additionally, the disproportionate ratio of specialty care providers to primary care centers often results in extended wait times for referrals, further exacerbating compliance issues with surveillance recommendations [16, 17, 20, 21].

These challenges are evident even in areas with relatively high concentrations of medical professionals, such as Boston, Massachusetts. Despite Massachusetts ranking third highest in the United States for the ratio of practicing ophthalmologists to overall population, rates of DR screening remain low [22]. Within the Mass General Brigham (MGB) health care system, the largest health care system in Massachusetts, many patients with DM do not regularly undergo DR screening [23]. This significant underutilization of care for DM patients in an urban area with numerous healthcare facilities highlights the need for innovative approaches to improve screening rates and overall diabetic eye care.

The purpose of this study is to evaluate the effectiveness of a novel teleretinal DR screening program in increasing compliance with DR screening recommendations in community health centers in the Boston area. To address this significant need for ophthalmic evaluation among DM patients in the Boston area, we implemented a primary care-based teleretinal DR screening program utilizing ultrawide-field fundus imaging across three community health centers in the MGB system. This screening program was designed to leverage technology to overcome urban-specific barriers to care, such as transportation issues and time constraints, thereby improving screening rates in underserved populations. By assessing the effectiveness of this intervention, we aim to contribute to the growing body of evidence supporting innovative approaches to improving diabetic eye care and potentially inform future healthcare policies and practices in urban settings.

Methods

Teleretinal screening program implementation

A teleretinal diabetic retinopathy (DR) screening program was implemented across three Mass General Brigham community health centers in the Boston area. The program rollout was staggered, with screening beginning at Site B in June 2021, followed by Site C in February 2022, and Site A in January 2023.

At each site, an UWF (Ultrawide-Field) Primary fundus camera (Optos PLC, Dunfermline, Scotland) was stationed. This clinically validated device captures 82% of the retina in a single image without requiring mydriasis, allowing for efficient and effective detection of disease [24]. Additionally, non-expert imagers in primary care clinics are able to oversee the imaging process utilizing this device [25]. The imaging system was directly integrated into the electronic medical record (EMR) to streamline workflow and data management.

Clinic staff, including coordinators and medical assistants, received comprehensive training on image capture techniques and ongoing feedback on image quality to ensure optimal results. Training consisted of a structured 30–60 min session led by program leadership or an Optos representative. The training covered patient data entry, proper imaging techniques, and criteria for acceptable image quality. Each site also received a detailed training manual with step-by-step instructions and example images illustrating common image quality issues (e.g., patient blinking, improper positioning). To ensure proficiency, sites completed one to two training sessions before launching operations, with retraining conducted as needed based on periodic image quality assessments. Each site designated a "project champion" responsible for mentoring new staff and maintaining adherence to imaging protocols.

A team of comprehensive ophthalmologists and retina specialists evaluated imaging using a standardized clinical protocol and provided recommendations for follow-up. Results were communicated to the patient's primary care provider, and when necessary, follow-up appointments were arranged with ophthalmologists. If an image was ungradable, patients were asked to return for re-imaging. When imaging quality prevented definitive assessment of a potential concern, a referral was placed to an ophthalmologist.

In order to integrate the teleretinal screening program with existing community-based care, a unique workflow for patient identification and referral was established at each health center based on pre-existing internal workflows and staff availability. At Site B, primary care providers identified patients needing screening and scheduled them for weekly dedicated screening clinics. At Sites A and C, the providers identified patients during their regular visits and obtained images on the same day. Program leadership conducted regular meetings with site teams to review progress, address challenges, and develop site-specific improvement plans.

Study design

We conducted a retrospective analysis on screening data from January 2020 to January 2024, encompassing the three community health centers where the DR screening program was implemented (both before and after implementation), and three comparison sites where the program was not implemented, selected due to their demographic similarity to the participating sites. The study was approved by the Institutional Review Board of Massachusetts General Brigham, and the need for informed consent was waived because of the retrospective nature of the study.

Data collection and statistical analysis

All patients with a diagnosis of DM that were seen at the included study sites as of January 1, 2020 were included in the registry for the current study. Individual patient encounter data, including the dates of all eye exams (or the lack thereof), was extracted from insurance claims and the electronic medical record. Compliance was defined as the completion of either teleretinal screening or a documented eye care professional examination within the previous 365 days, in accordance with established guidelines from the American Academy of Ophthalmology for diabetic retinopathy surveillance [3]. This definition was selected to ensure comparability with prior studies evaluating annual screening rates [9, 26, 27]. Patients were classified as "in compliance" if, on a given date, they had received an eye exam within the past 365 days and designated as "not in compliance" otherwise. We analyzed compliance rates beginning January 1, 2021 so that we had a full year of prior data to determine compliance status before the first participating site implemented the screening program, and followed compliance rates through January 1, 2024. We then aggregated the individual level data to monthly compliance rates at each site, calculated as the proportion of patients who adhered to annual screening guidelines, either through teleretinal screening or a documented examination by an eye care professional. Statistical analysis was performed using R, version 4.4.2.

Our primary analytic approach to estimate the causal impact of the teleretinal screening program on compliance rates was a two-way fixed effects (TWFE) regression specification. In TWFE, we regressed the monthly compliance rate in each site on (1) indicator variables for each site, to account for time-invariant differences between sites, (2) indicator variables for each year-month combination (e.g., January 2021, February 2021, etc.), to account for common time trends across sites, and (3)

our focal variable, an indicator variable for whether the screening program was "active" in a given site at a given time. Thus, the participating sites transitioned to "active" status at some point in our study time period, while the comparison sites never implemented the screening program. We analyzed patient data from their initially assigned site as of January 1, 2020. Patients were assigned to sites based on the location of their primary care physician. Thus, we were estimating an intention-to-treat (ITT) effect of the screening policy on the participating sites. While some patients undoubtedly left their initial sites for a variety of reasons, such factors did not bias our results as long as the patterns were the same in the comparison sites.

To provide a causal estimate of the effects of the screening program on compliance rates, we required the assumption that in the absence of the screening program, the time trends in compliance rates across participating sites would have been the same as that observed in the comparison sites. While this assumption was not testable, we examined the similarity of trends in the pre-implementation period to assess its tenability. As a sensitivity check, we conducted an event study analysis using the approach of Callaway and Sant'Anna to allow for varying effects across site and across time, as the TWFE model only provided the average effect under the assumption that the effects are constant [28, 29].

Results

As of January 1, 2020, a total of 10,247 patients with a diagnosis of DM who had been seen by primary care providers at the study sites were included in the registry, yielding 222 monthly compliance rates across the six sites through January 1, 2024. Figure 1 shows monthly compliance rates by site, with lines color coded to represent whether the screening program was implemented at that time (blue) or not (red). The dashed black line shows the "parallel trend"—the estimate of what the compliance rates would have been in the participating sites had the program not been implemented, derived from the TWFE model. Initial compliance rates across all sites prior to implementation of the screening program range from 25 to 40%, with pre-implementation trends similar for both the intervention and comparison sites.

After introduction of the screening program, compliance rates increase in the intervention sites. These results are quantified with the TWFE model. Table 1 shows a significant positive impact, with the screening program causing an average increase in DR compliance rates of approximately 7.2% points ($p < 0.001$). Figure 2 shows the results of the event study analysis that allows the effect

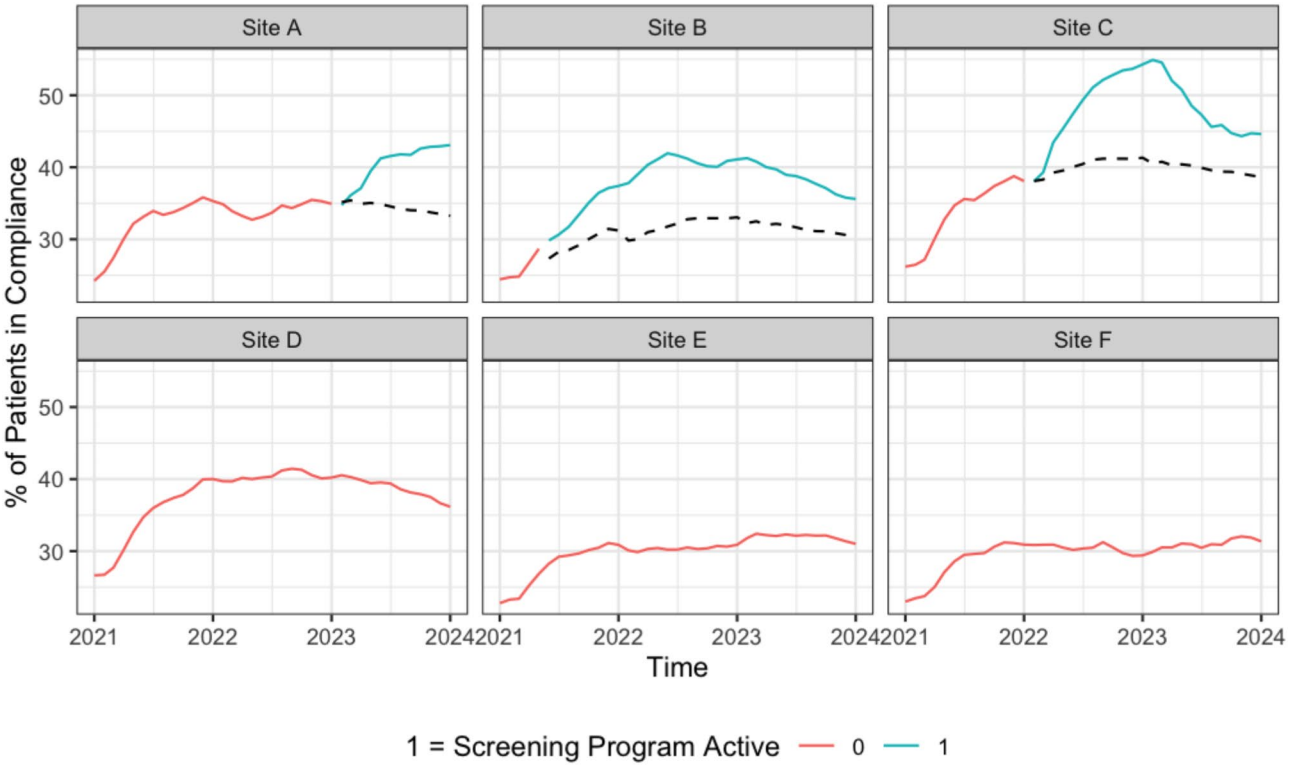

Fig. 1 Diabetic retinopathy evaluation compliance rates by site (monthly). Sites A, B, and C are the intervention sites and Sites D, E, and F are the comparison sites. The dashed black line represents the "parallel trend" that would be expected in the participating sites had the screening program not been implemented, derived from the two-way fixed effects regression model

Table 1 Results of two-way fixed effects regression model estimating the effect of teleretinal screening program implementation on monthly compliance rate

	OLS		Cluster Robust	
Predictors	***Estimates***	***std. Error***	***Estimates***	***std. Error***
active	7.21 ***	0.62	7.21 ***	1.92
Observations	222		222	
R^2 / R^2 adjusted	0.997 / 0.996		0.997 / 0.996	

Estimates derived from an ordinary least squares (OLS) regression model with fixed effects for month, site, and an indicator variable for whether the teleretinal screening program was operational (denoted "active" in the table). The second model clusters the standard errors by site. The month and site fixed effects are omitted from the table.

*** $p<0.001$

of the screening program to vary over site and over time. While the effect is positive across all sites, it appears to fade over time after an initial spike. Notably, the parallel trends assumption appears reasonable in the pre-implementation period, strengthening the internal validity of these findings. The average effect from the TWFE model is indistinguishable from the average effect from the event study model (7.0% points, $p<0.001$).

In addition to compliance outcomes, image quality was also assessed. Across all sites, 7% of images were ungradable, requiring either repeat imaging or referral for further evaluation.

Discussion

The implementation of a community-based teleretinal diabetic retinopathy (DR) program significantly improved compliance with annual screening guidelines for DR in underserved, urban communities. Our results demonstrated a significant increase of 7.2% points in compliance rates across the included sites, underscoring the potential of teleretinal screening to enhance healthcare delivery for people with diabetes. This increase is particularly important given that non-compliance with DR screening is a key contributor to delayed diagnosis and treatment, increasing the risk of irreversible vision loss. Additionally, studies have demonstrated that implementation of screening programs may enhance subsequent health care behaviors such as adherence to comprehensive dilated eye examinations with an ophthalmologist [30, 31].

The observed 7.2% point increase in screening compliance aligns with previous studies conducted in other practice settings that similarly demonstrated increases in DR screening compliance with teleretinal screening implementation ranging from 10 to 25% points [9, 26, 27, 31, 32]. Our more modest increase may be attributed to

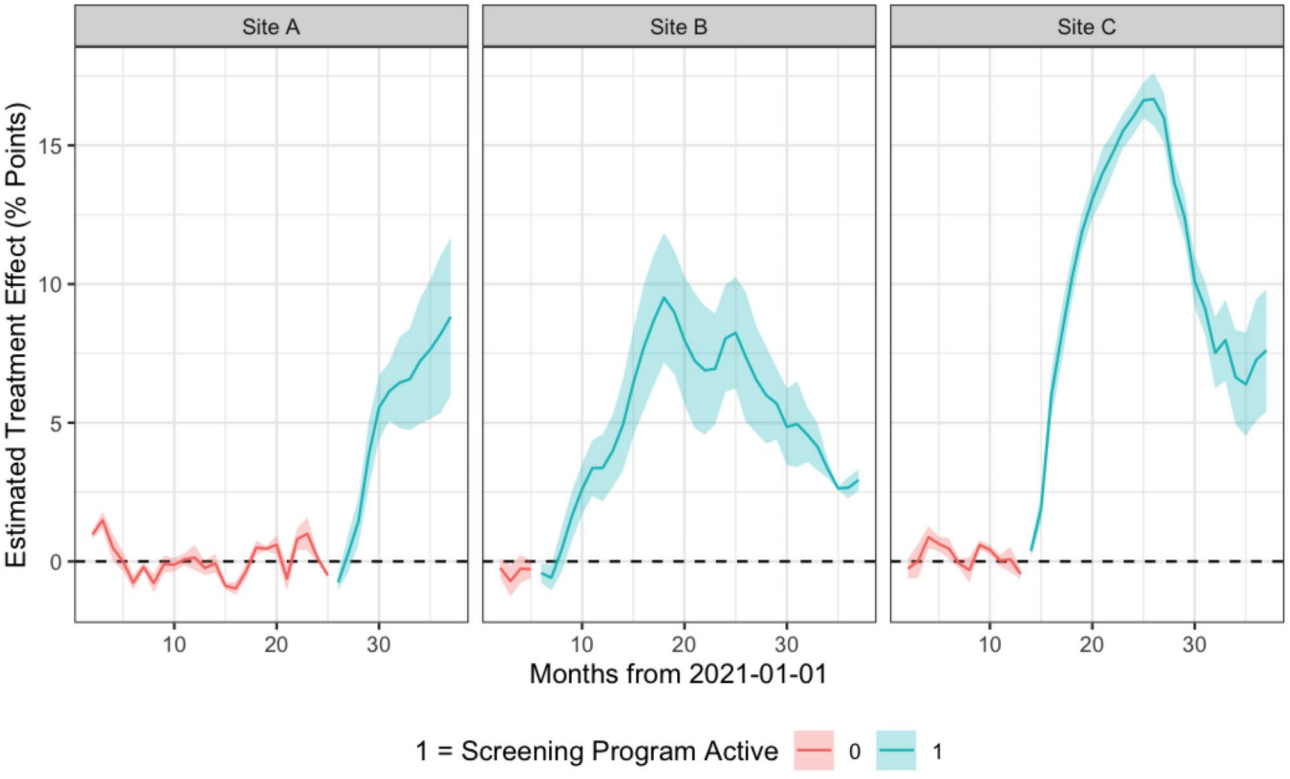

Fig. 2 Effects of teleretinal screening program on diabetic retinopathy screening compliance at each site over time. The figure shows the estimates and 95% confidence intervals from the event study analysis. Results are derived from the Callaway and Sant'Anna estimator that allows for heterogeneous effects by site and over time

several factors. First, with only two years of follow-up at Site B and one year at Site C, our study had a relatively short observation period compared to some long-term studies. Mansberger et al.'s study, for example, showed that the full impact of telemedicine screening became more apparent over time, with the greatest increases in compliance occurring after the first two years [33]. Longer-term follow-up might reveal greater increases in compliance as workflows become more refined and both patients and providers become more accustomed to the program. However, it is also possible that with time the initial surge in compliance may fade as the novelty of the program wears off, indicating the need for sustained program promotion and engagement, as suggested by Fig. 2. Second, while many previous studies focused on rural areas with limited access to eye care specialists, our program was implemented in an urban setting. The impact of teleretinal screening might be less dramatic in urban areas where traditional eye care services are more readily available, though still underutilized due to other barriers.

Despite the lower magnitude of increase compared to some previous studies, these findings still demonstrate a significant improvement in screening compliance. Moreover, the impact of our program may extend beyond the direct increase in screening rates. Studies have shown that implementation of screening programs can enhance subsequent health care behaviors, such as adherence to comprehensive dilated eye examinations with an ophthalmologist [30, 31]. This suggests that the long-term impact of the program may be greater than what is captured by the immediate increase in screening rates alone.

The success of the implemented teleretinal screening program can be attributed to several factors. First, by locating imaging equipment at community health centers, the program lowered geographic and logistical barriers to care, including transportation issues and the need for time off work [34]. Additionally, by integrating teleretinal screening into existing care workflows and allowing patients to be screened during routine primary care visits, the program reduced the need for patients to attend a separate ophthalmology appointment or undergo dilation of the eyes. This convenience likely contributed to the increased compliance rates. Moreover, the program allowed for rapid image acquisition and evaluation, thereby minimizing delays in referral for patients needing further care.

This integrated workflow not only streamlined care delivery but also mirrored successful strategies used in other healthcare systems with high DR screening adherence. Similar policies in countries such as the United Kingdom, Denmark, and Iceland have demonstrated the effectiveness of nationwide screening programs in improving compliance and reducing vision loss [35–37]. For instance, the United Kingdom's National Health Service (NHS) systematically invites all individuals aged 12 and older for screening, achieving an overall compliance rate of 82.8% and significantly decreasing DR-related blindness [38]. Incorporating lessons from these models, such as automated patient reminders and centralized data tracking, could further strengthen our screening program, ensuring sustained adherence and improved patient outcomes.

Our analysis revealed some variation in the screening program's impact across different sites, which could be due to differences in the timing and nature of program implementation given slight variations in program workflow were allowed in order to accommodate practices at each individual site. The staggered implementation of the program over three years may explain some of the observed differences in compliance rates, with sites having a longer operational period demonstrating higher compliance. Additionally, workflow differences between sites, such as pre-scheduled screening at Site B versus opportunistic screening at Sites A and C, may have influenced the ease of integrating screening into routine care and thus affected compliance outcomes. These findings suggest that while the program was successful overall, site-specific adjustments may be needed to optimize effectiveness. Regardless, there remained a net increase in compliance throughout follow-up after implementation at all of the intervention sites. Due to the design of the current study, it is possible that factors beyond the teleretinal screening program itself may have contributed to the observed increase in compliance. For example, the physical placement of the imaging device and promotional efforts through posters and educational materials may have raised awareness about the importance of DR screening among both patients and providers [39]. This increased awareness could have led to more patients seeking eye care, even outside of the teleretinal screening program. Furthermore, providers at the community health centers may have been more vigilant in recommending screening once the program was introduced, further driving compliance. While the results are promising, additional research is necessary to disentangle the relative contributions of these external factors from the direct effects of the teleretinal screening program. Future studies could explore the impact of targeted patient education or provider incentives on DR screening compliance in conjunction with telemedicine programs. Additionally, incorporating qualitative data from individuals with poor compliance to screening could provide valuable insights into barriers to participation in order to inform tailored interventions to improve screening uptake.

The low rate of ungradable images (7%) observed in our study supports the feasibility of using ultrawide field fundus (UWF) cameras in primary care settings, particularly

in underserved areas where trained ophthalmic personnel may be limited. Notably, the UWF camera used in our study was specifically designed for use by non-expert imagers, and our results align with prior studies, which report ungradable image rates ranging from 2.8 to 13% for other UWF devices [40, 41]. These findings suggest that the level of training provided was appropriate for maintaining adequate image quality.

Several limitations should be considered when interpreting these findings. First, the study was conducted exclusively within our large, northeastern, academic health system, which may limit generalizability to other regions. While the overall patient population in the MGB system is predominantly white, the demographics at our program sites varied: Site B is predominantly White, whereas Sites A and C serve a predominantly Hispanic population. We made efforts to select comparison sites with similar racial and ethnic backgrounds to these intervention sites. Most patients seen through the screening program were insured, with many enrolled in Medicare or Accountable Care Organization (ACO) plans from MGB. Second, while we utilized comparison sites with similar characteristics to the intervention sites and collected data both pre and post screening program implementation, a causal interpretation of our results requires the assumption that, in the absence of the screening program, the trends in compliance rates would have been the same in both groups. While this assumption was untestable, the similarity in trends between sites in the pre-policy period provided some evidence that it was tenable. However, it was nonetheless possible that unobserved factors not assessed in the current analysis, such as staff turnover leading to the hiring of providers who were more or less proactive in referring patients for screening, may have influenced compliance rates in only one of the groups. Additionally, while we attempted to use claims data to account for patients who received care outside of the MGB system, this method can be incomplete. However, this limitation likely impacted both intervention and comparison groups equally, and therefore was unlikely to substantially influence these results. Finally, while we demonstrated an increase in compliance, this study did not assess long-term clinical outcomes such as reductions in DR progression or vision loss, which could be assessed through future studies.

An important consideration for future iterations of the screening program is the impact of extended screening intervals, with some organizations recommending intervals of up to every two years for certain populations [4]. While extended intervals may reduce the burden on patients by minimizing the frequency of visits, it remains unclear whether this would positively or negatively affect attendance rates in our model. Although extended intervals could make participation more feasible for patients, it is possible that reduced screening opportunities might result in lower engagement, particularly for populations that benefit from frequent reminders or reinforcement during routine care. Future research on the long-term effects of extended screening intervals could help clarify their impact on compliance and patient outcomes.

Our findings highlight the potential of telemedicine-based DR screening programs to increase compliance with annual screening guidelines, thereby facilitating earlier detection of DR and reducing the risk of vision-threatening complications. The success of this program in an urban, underserved population suggests that similar initiatives could have far-reaching public health benefits if expanded to other vulnerable communities. However, the modest 7.2% point increase in compliance also underscores the challenges these programs face, such as competing priorities in primary care for other screenings and health maintenance, as well as increasingly limited resources for support staff due to financial constraints in healthcare systems. Integrating teleretinal screening into value-based care models may enhance cost-effectiveness by reducing the need for more intensive, late-stage DR treatments. Future efforts should focus on long-term follow-up studies to assess the sustained impact of teleretinal screening programs on compliance rates and clinical outcomes, optimizing teleretinal workflows, and addressing potential barriers to sustained compliance. Investigating the role of patient education, provider engagement, and system-level incentives in maintaining high compliance rates will be critical for the long-term success of these programs.

Conclusions

Our study demonstrates the potential of telemedicine-based DR screening programs to increase compliance with annual screening guidelines, thereby facilitating earlier detection of DR and reducing the risk of vision-threatening complications. While additional research is needed to further explore the program's long-term impact and cost-effectiveness, as well as optimize the implementation across sites, these findings provide strong support for the expansion of teleretinal screening as a strategy for preventing vision loss due to DR in vulnerable populations.

Abbreviations

DM	Diabetes mellitus
DR	Diabetic retinopathy
MGB	Mass General Brigham
TWFE	Two-way fixed effects

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Not applicable.

Authors' contributions

SH, JG, CR, EL, and AL conceptualized the study. EL extracted the data from relevant databases. JG performed the cleaning and analysis of data. SH and

JG led the interpretation of data and drafted the manuscript. CR provided project oversight. CR, EL, and AL provided critical input into the organization, analysis, and interpretation of the results. All authors read and approved the final manuscript.

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Data availability
The data analyzed in this study are proprietary. However, we share a simulated version of the data set based on the results of our model. The simulated data and the analysis code used in this study are available at the following URL: https://doi.org/10.7910/DVN/T5HXUE.

Declarations

Ethics approval and consent to participate
Ethics approval was obtained from the Institutional Review Board of Massachusetts General Brigham, and the need for informed consent was waived because of the retrospective nature of the study. This study was in compliance with the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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