



Published in final edited form as:

Ophthalmology. 2025 September ; 132(9): 1033–1044. doi:10.1016/j.ophtha.2025.04.027.

Michigan Screening and Intervention for Glaucoma and Eye Health through Telemedicine Program: Impact on Vision, Follow-up, and Costs

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Abstract

Purpose: To evaluate the impact of the Michigan Screening and Intervention for Glaucoma and Eye Health through Telemedicine Program (MI-SIGHT) on visual acuity (VA), vision-related quality of life (VRQOL), satisfaction, follow-up visit attendance, and costs among medically underserved participants receiving primary care at community health centers.

Design: Prospective cohort study with an embedded randomized controlled trial.

Subjects: MI-SIGHT participants ≥ 18 years.

Methods: MI-SIGHT participants underwent an eye disease screening exam with a trained ophthalmic technician, received assistance ordering low-cost glasses, and completed surveys. Participants could return for a repeat screening after 1 year. The prevalence of disease identified was compared to national rates using z-tests. VA and VRQOL were compared between initial and

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The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Conflict of Interest: No conflicting relationships exist for any authors.

Meeting Presentation: American Academy of Ophthalmology 2024 Annual Meeting, Poster Discussion, October 20, 2024

repeat visits with paired t-tests and Wilcoxon signed-rank tests. Satisfaction was summarized with descriptive statistics. Participants who screened positive for disease were assessed for attendance at recommended follow-up with a clinician, including those with glaucoma who were randomized to care navigation plus personalized education and health coaching (treatment) or care navigation plus written education (control). Attendance rates were calculated and compared between arms of the trial with Chi-Square tests.

Main outcomes measures: 1) Eye disease prevalence; 2) Change in VA and VRQOL; 3) Program satisfaction; 4) Follow-up attendance; 5) Costs.

Results: 3714 participants were included; 11.5% were visually impaired, 9.3% had un- or undercorrected refractive error causing visual impairment; 22.4% had glaucoma/suspected glaucoma; 4.7% had diabetic retinopathy (rates higher than national averages at $p < 0.0001$); 99% were satisfied or very satisfied, and 68% attended recommended follow-up. 943 participants completed repeat screening (mean of 1.2 ± 0.3 years after initial screening). At repeat screening, worse eye presenting logMAR VA improved (mean $\pm$ SD, 0.25 ± 0.59 to 0.21 ± 0.52 , $p = 0.0012$) as did VRQOL (NEI VFQ9 composite score 81.1 ± 14.1 to 86.4 ± 12.0 , $p < 0.0001$). Of the 490 participants who screened positive for glaucoma/suspected glaucoma and were randomized ($n = 247$ treatment, $n = 243$ control), follow up attendance did not differ (61% vs 59% $p = 0.7$). The program cost \$110.99/participant served, and \$206.72/case of eye disease detected.

Conclusions: Expanding glaucoma and eye disease screening and treatment of refractive error to community health centers with care navigation support could improve vision and eye health outcomes.

Precis

The Michigan Screening and Intervention for Glaucoma and Eye Health through Telemedicine Program detected higher rates of glaucoma/suspected glaucoma than national averages; improved participants' vision and vision-related quality-of-life; helped 68% of participants access follow-up care.

Keywords

glaucoma screening; eye disease screening; vision related quality of life; costs; attendance at follow up

On July 23, 2021, every member nation of the United Nations (UN) unanimously adopted the "Vision for Everyone" resolution, calling on member countries to ensure full access to eye care services, and to make access to eye health integral to each nation's "commitment to achieving the Sustainable Development Goals" set forth by the UN.¹ The world-wide recognition of the importance of vision to economic productivity and quality of life is a milestone. It marks the hard work of many organizations worldwide in shining light on the profoundly negative impact of vision loss on a person's life trajectory. It recognizes the persistent burden of uncorrected refractive error, eye disease, and inequities in eye disease outcomes, particularly in glaucoma which is asymptomatic until late in its course. Hispanic Americans alongside Americans living with lower socio-economic status are more likely to report not wearing eyeglasses because they are unaffordable.² Glaucoma and diabetic

retinopathy remain the leading causes of irreversible blindness among Black and Hispanic Americans with rates twice as high in these groups as compared to White Americans.^{2–6}

In the United States, the National Academy of Science, Engineering, and Medicine (NASEM) issued a call to action to make “eye health a population health imperative” in 2016.⁷ The Centers for Disease Control and Prevention (CDC) focused efforts on improving public eye health since 1991, and, in 2007, the Vision Health Initiative emerged as a group dedicated to public eye health within the Epidemiology branch of the Division of Diabetes Translation. The Vision Health Initiative has funded and coordinated multiple research programs to identify and treat glaucoma and other eye diseases in high-risk communities. This research led to innovative community-based outreach strategies, including telemedicine to support providing care at Primary Care Provider offices, Federally Qualified Health Centers (FQHCs), mobile vans at community centers, local Walmart stores, low-income senior housing buildings, and community clinics, in different geographic areas around the country.^{8–12}

This manuscript focuses on the outcomes from one program funded by the CDC to identify and treat glaucoma and other eye diseases in high-risk communities called the Michigan Screening and Intervention for Glaucoma and Eye Health through Telemedicine (MI-SIGHT) program.¹¹ High-risk communities are defined as communities with social risk factors associated with higher rates of glaucoma and other eye disease and worse access to high quality eye care. These social risk factors include high rates of poverty and high rates of un- or under-insurance, which often are associated with other risk factors such as lack of stable transportation, housing, and safety, among others.¹³ The MI-SIGHT program used community-engaged research to implement a telemedicine program in two primary care clinics. The MI-SIGHT program was guided by a Community Advisory Board comprised of clinicians, administrators, patients, and researchers from the two clinics and researchers at the University of Michigan (UM).

In the MI-SIGHT program, ophthalmic technicians at the community clinics obtain an eye health history and conduct ophthalmic testing, these data are sent through the electronic health record (EHR) to UM eye physicians for review and interpretation. Screening for all five leading causes of visual impairment (refractive error, cataract, glaucoma, diabetic retinopathy, and macular degeneration) is performed, alongside screening for other less common causes of visual impairment detectable on fundus imaging. The ophthalmic technicians act as care navigators and assist participants in choosing and ordering low-cost glasses through an on-line retailer. If pathology is detected, the patient is referred to eye clinicians, through partnered relationships, to offer affordable treatment. If glaucoma/suspected glaucoma is detected after screening, participants are enrolled in a randomized trial of care navigation plus personalized education and health coaching (treatment) versus care navigation plus written education (control) on adherence to recommended follow-up attendance with an eye clinician. This manuscript first serves to detail the socio-demographic characteristics, clinical findings, satisfaction, attendance at recommended follow-up for those who participated in the MI-SIGHT program over 3.5 years, and whether attendance at recommended follow-up differed between arms of the embedded trial of care navigation and personalized coaching vs care navigation and written education. The second

purpose of the manuscript is to describe the change in presenting visual acuity and self-reported visual functioning among those who returned for a second screening examination. The third purpose is to describe program costs per participant served, costs per case of eye disease detected, and costs per case of glaucoma/suspected glaucoma detected.

Methods

Observational Study

The study was approved by the Institutional Review Board at the UM (UM00169371) and adhered to all Tenets of the Declaration of Helsinki. The clinical trial component of the study is registered at [clinicaltrials.gov](https://clinicaltrials.gov/ct2/show/study/NCT04274764) (NCT04274764). Study data were collected and managed using REDCap electronic data capture tools hosted at UM.^{14,15} The MI-SIGHT program was conducted in two clinics serving low-income communities with large proportions of Black and Hispanic residents: a free clinic in Ypsilanti, Michigan (MI) and a Federally Qualified Health Center (FQHC) in Flint, MI. Due to different program start times at each site, participants were recruited from July 28, 2020 until January 27, 2024 at the free clinic, and from January 27, 2021 until January 27, 2024 at the FQHC. Participants were recruited by various methods including directly calling patients referred by clinicians at the free clinic, calling patients with diabetes who were overdue for their annual eye exam at the FQHC, and outreach within the communities.¹⁶

Community residents ≥ 18 years of age were eligible to participate. We excluded those with: 1. significant eye pain; 2. sudden decrease in vision within one week; 3. binocular diplopia; 4. cognitive impairment (assessed as inability to answer screening questions); 5. pregnancy; 6. incarceration; or 7. moving outside of driving distance to the clinic within 6 months. Those with eye pain, a sudden decrease in vision, or binocular diplopia were directly referred for medical treatment. Written informed consent was obtained. Full consent forms were provided in English, Spanish, Albanian, and Arabic, and short form consents were provided in Mandarin, French, Hindi, Korean, Igbo and Tagalog. Those who did not speak one of these languages were excluded from the study.

After obtaining informed consent, an ophthalmic technician completed a health history and surveys with the participant. This included the 9-item National Eye Institute Visual Function Questionnaire (VFQ9) to assess visual function and vision-related quality of life.¹⁷ Each question is asked on a 5- or 6-point Likert scale, coded from 0 to 100 with larger values indicating better visual function. The questionnaire is scored overall and for the 7 subscale domains as a mean of items included.

Full details of the MI-SIGHT methodology have been previously published.¹¹ Briefly, the examination by the ophthalmic technician included measures including presenting visual acuity (VA), refractive error with autorefraction and manifest refraction, best corrected visual acuity (BCVA), interpupillary distance, pupillary response, anterior chamber angle assessment by penlight, extraocular motility and gross alignment, central corneal thickness, and intraocular pressure (IOP) by iCare tonometer. If the IOP was below 30 mm Hg and participants did not have a narrow angle, the ophthalmic technicians continued with dilation of the eyes. Images were then taken including external photographs, images of the posterior

pole, and optical coherence tomography (OCT) images of the macula and retinal nerve fiber layer (RNFL) (Maestro2, Topcon, Tokyo, Japan). If any urgent or emergent conditions were identified, the ophthalmic technician immediately paged the ophthalmologist at UM or the ophthalmologist at the FQHC to ensure appropriate care. After the examination, the ophthalmic technicians helped participants with refractive error select low-cost eyeglasses frames ([ZenniOptical.com](https://www.zenni.com)), and placed the order after the prescription was confirmed by the ophthalmologist. Remote ophthalmologists at UM reviewed the MI-SIGHT participant screening data. The remote ophthalmologists first designated whether images were gradable or ungradable and then assessed whether the following vision and eye diseases were present: visual impairment (BCVA $\leq 20/40$ in the better seeing eye), refractive error, cataract, glaucoma, macular degeneration, and diabetic retinopathy, alongside any other incidental findings, and made follow-up recommendations.^{11,18} Case definitions are provided in our Methods paper.^{11, 20} Program satisfaction was assessed by survey. Participants who screened positive for eye disease were referred to an ophthalmologist at nearby UM satellite clinics, their established ophthalmologist, or an ophthalmologist at the UM free clinic. Adherence to recommended follow-up for participants who had pathology detected (all of which was referred for follow up in one year or less) was assessed. Participants without eye disease detected were referred for repeat screening according to age-related guidelines.¹⁹ All participants enrolled in the first two years of the study, regardless of whether eye disease was detected, were invited to return for a repeat visit one year later, where the same protocol was followed, to assess change in vision-related quality of life, change in presenting VA, and incident glaucoma/suspected glaucoma.

Embedded Randomized Controlled Trial

If a participant screened positive for glaucoma or suspected glaucoma, follow-up was recommended in < 1 year. Participants screening positive for glaucoma were then randomized 1:1 using block randomization, stratified by site, to care navigation plus standard written education or care navigation plus personalized education and motivational-interviewing-based health coaching. Care navigation included the ophthalmic technician assessing and assisting with insurance and scheduling care with a local ophthalmologist that aligned with the participant's insurance status, including a free clinic for those who could not obtain insurance. Standard written education included the UM Kellogg Eye Center handout about glaucoma/suspected glaucoma, written at $\leq 8^{\text{th}}$ grade reading level. For the coaching intervention, the ophthalmic technicians received glaucoma-specific motivational interviewing training²⁰ and achieved competence in it prior to the trial, as measured by motivational-interviewing trainers grading audio-recorded practice patient sessions (competence defined as a mean Likert scale score ≥ 5 across items on the modified One-Pass rubric).^{21,22} The coach used a web-based application (www.seeglaucoma.org) that generated personalized glaucoma education and guided the coaching session through sharing engaging audio-visual content on a tablet. The coach walked the participant through their screening results and what will happen to their vision if glaucoma goes untreated.¹¹ The coach elicited an understanding of what motivates that participant to maintain their vision. The coach explores what unique obstacles the participant has to engaging in follow-up care, and how motivated they are to attend. The coach and study participant then created a concrete "action plan" that delineated the short-term plan of steps the study participant will take to address

any identified barriers to follow-up care, which can include addressing motivational factors in a subsequent phone visit. The coach and study participant also created a list of questions for the participant to ask the ophthalmologist at their recommended follow-up visit. The outcome measure is attendance at the recommended follow-up appointment, within a six-month window. Our *a priori* power calculation, using the assumptions that our baseline no-show rate was 20% at the Hope Clinic free eye clinic and we wanted to detect a 50% improvement (ie, from 20% to 10%), we would need (with $\alpha = 0.05$ and power = 80%) to enroll 200 people to each treatment arm for 400 total participants.¹¹

Statistical Methods: Characteristics of the MI-SIGHT participant cohort were summarized with descriptive statistics (mean, standard deviation [SD], median, frequency, and percentage), overall and stratified by site. Differences between sites were investigated and tested with 2-sample t-tests, 2-sample Wilcoxon tests, Chi-square, and Fisher's exact tests. Snellen VA was converted to LogMAR equivalent for all analysis. Values of count fingers, hand motion, light perception, and no light perception were approximated by Snellen VAs of 20/4000, 20/40000, 20/400000, and 20/4000000000, respectively, before conversion to logMAR. VA measures greater than 20/20 were trimmed to 20/20. The ungradable rates for fundus photographs and OCTs were tallied. The observed prevalence of disease found during screening was compared for differences from national prevalence rates using 1-sample, 2-sided z-tests of proportions. For the subset of MI-SIGHT participants who returned for repeat screening, presenting VA and self-reported visual function were compared between the initial and repeat screening visits with paired t-tests and Wilcoxon signed-rank tests. Participant characteristics between those who returned for in-person repeat screening, phone repeat screening, or no repeat screening were compared for differences using ANOVA, Kruskal-Wallis tests, and Chi-Square or Fisher's exact tests. Incident rates of glaucoma were also estimated by comparison of initial and repeat screening results. Program satisfaction was summarized with descriptive statistics, overall and stratified by site. Satisfaction was compared between sites with Fisher's exact tests. Attendance at recommended follow-up with an ophthalmologist was summarized descriptively with frequencies and percentages for those participants whose screening revealed they were high-risk referrals (referred for care in ≤ 1 year) and separately for the subset of participants who screened positive for glaucoma and were included in the randomized trial. Differences in rates of attendance were compared between arms of the randomized trial with Chi-Square tests. Multiple comparison adjustment was performed using Holm's procedure. All analysis was performed with SAS version 9.4 (SAS Institute, Cary, NC).

Cost Analysis: Two cost analyses were conducted using an accounting approach: a macro-cost analysis and a micro-costing method. The macro-cost analysis was undertaken to understand overall programmatic costs for implementing a new screening program in a community clinic, while the micro-cost activity-based analysis was used to understand the cost of adding a screening program to an already existent eye clinic infrastructure. For both analyses, we excluded all costs related to research, including data collection, data management, IRB approval, and study administration and oversight. For the macro-cost analysis, we included the costs of all equipment and supplies purchased for screening, which we tallied from financial records, as this equipment were purchased specifically for

the screening program. We then amortized the equipment cost over an assumed useful lifespan of ten years; we assumed there was no deterioration. There were no rental costs. Percent of full time equivalent (FTE) of salary and fringe devoted to clinical activity to carry out the screening activities, clinical administrative duties including having an ophthalmologist available to triage urgent matters, care navigation, and recruitment and outreach to maintain program volume was estimated for all MI-SIGHT team members. For the micro-cost analysis, we included the costs of equipment and supplies as though the program would be added to existent infrastructure, an eye clinic in an FQHC may not be likely to own the technology-based equipment used in the eye disease screening. In the micro-cost analysis, the cost of the equipment was also amortized over ten years and we assumed no depreciation. There were no rental costs. The micro-costing analysis used the Activity-Based Costing method where the ophthalmic technicians logged time spent to conduct the refraction and eye disease screening and ophthalmologists logged time spent for interpreting the screening testing and sending a results letter to the participant and PCP.^{23,24} As the ophthalmic technicians did not log minutes spent managing the program, we multiplied their recorded time by a factor of 3 to arrive at a more realistic estimate to follow the methods of the NYC-SIGHT program.²³ The time costs were converted to dollars by multiplying hourly wage rates from the 2021 US Bureau of Labor Statistics (BLS) by the time spent by each staff member on screening tasks. The BLS estimates that ophthalmic technicians earned \$19.77/hour and ophthalmologists earned \$129.85/hour in 2021.²³ Personnel costs were then inflated by 30.4% to account for fringe benefits.²³

Results

A total of 3766 participants were enrolled in the MI-SIGHT program, including 1639 participants at the free clinic and 2127 participants at the FQHC (Figure 1). After excluding those participants who withdrew and therefore did not complete screening (n=52), a total of 3714 participants' data was analyzed (1605 free clinic; 2109 FQHC). Participants were on average 54.1 years old (SD=15.9), 37.5% identified as male, 31.8% reported their race as White and 52.0% as Black or African-American, 19.0% reported Hispanic ethnicity, 20.2% did not speak English as their primary language, 42.1% had a high school education or less, 63.5% earned less than \$30,000 per year, and 23.8% did not have health insurance. Self-reported health history showed that 24.3% of participants had diabetes, 45.5% hypertension, 17.2% currently smoked, 5.0% had glaucoma, and 60.8% had not had a dilated eye exam in >2 years. Many differences existed between the two sites (Table 1) and are discussed in prior publications.^{18,25} The ungradable rate for imaging was 2.6% for fundus photos and 2.9% for OCT images.

Screening results revealed varying rates of pathology (Table 2). Visual impairment in the better seeing eye existed in 11.5% of participants and was significantly higher than the national prevalence rate of 2.2% ($p<0.0001$).²⁶ Uncorrected or under-corrected refractive error (presenting VA $\leq 20/50$ corrected to $\geq 20/40$ in the better seeing eye) was observed in 9.3% of participants, significantly larger than the reported national rate of 5.3% ($p<0.0001$).²⁷ Cataract was observed in 22.9% of participants and included both visually significant (6.3%) and non-visually significant cataracts (16.6%). The observed rate of all forms of cataract was significantly larger than the national rate of 17.0% ($p<0.0001$).²⁸ The

observed prevalence of glaucoma/suspected glaucoma was 22.4%, which is significantly larger than national rates of glaucoma/suspected glaucoma using different populations (13.6% of Medicare beneficiaries, 0.97% of Medicaid beneficiaries, 1.66% of commercially insured beneficiaries,²⁹ and 1.62% of adults >18 years old in the US with definite glaucoma³⁰; all $p<0.0001$). Definite glaucoma adjudicated by glaucoma specialists using population-based data from NHANES among adults in the US >18 years old is estimated at 1.62%³². To better compare our rate of definite glaucoma to this population based-estimate most similar to our included population, we analyzed the subset of participants who screened positive for glaucoma/suspected glaucoma and returned for in-person exam and visual field and we were able to obtain their record ($n=349$). In this sample, 196 were classified as glaucoma suspect, 107 as definite glaucoma, and 46 as no glaucoma. Thus, in our sample, at the lowest and most stringent end of estimation, we had a 5.3% (196/3714) prevalence of glaucoma suspect and 2.9% (107/3714) prevalence of definite glaucoma, and 2.9% is still significantly higher ($p<0.0001$) than the 1.62% national rate of definite glaucoma reported from NHANES. The observed prevalence of diabetic retinopathy was 4.7% and was higher than national rates (3.4%).³¹ Other pathology was found in 15.1% of participants, ranging from 0.1% of participants with Hollenhorst plaque, vascular occlusions, optic disc swelling, or ptosis obscuring vision, to 1.9% of participants with hypertensive retinopathy (Supplemental Table 1).

Of the 3714 sample, a total of 943 participants had a repeat screening (410 free clinic; 533 FQHC; Figure 1). These repeat screenings were on average 1.2 years after initial screening ($SD=0.3$, median = 1.1, range=0.5 to 2.9). The majority of repeat screenings were in-person (81%, 766/943) and a minority were phone screenings to collect survey data (19%, 177/943). A comparison of participants who had in-person repeat screening, phone repeat screening, or no repeat screening but a year had passed from their initial screening is presented in Supplemental Table 4. Participants with in-person repeat screening had significantly better presenting logMAR VA at their initial screening ($p=0.0012$), were more educated ($p<0.0001$), reported larger household income ($p=0.0060$), were more likely to have healthcare insurance ($p=0.0091$), and more likely to report their primary language was English ($p=0.0060$) compared to those with phone screening and/or those who had no screening. Participants with a repeat screening had a significant improvement in presenting logMAR VA of the worse eye from their initial screening (mean $\pm$ SD, 0.25 ± 0.59 and 0.21 ± 0.52 , respectively; $p=0.0012$; Table 3). Participants reported significant improvement in visual function (VFQ9) between the initial and repeat screenings for the overall composite score (81.1 ± 14.1 and 86.4 ± 12.0 , respectively; $p<0.0001$) and all subscales (Table 3). Site stratified changes in logMAR VA and visual function between initial and repeat screenings showed average improvements, however some results had reduced statistical significance due to the reduced power from subgroup analysis (Table 3). Lastly, compared to initial screening results, repeat screening revealed the incident rate of glaucoma/suspected glaucoma was 6.4% (49 of 763).

Participants reported high satisfaction with the MI-SIGHT program (Supplemental Table 3). Overall, 99% of participants reported they were very satisfied (91.6%) or satisfied (7.7%) with their eye screening visit, 99% reported the program was very convenient (89.2%) or convenient (9.5%), and 99.2% reported they were very likely (93.2%) or likely (6.0%)

to recommend the program to a family member or friend. No differences in program satisfaction were observed between sites (all $p>0.05$). Most participants ordered eyeglasses through the program (overall: 68% [2517 of 3714], free clinic: 60% [955 of 1605], FQHC: 74% [1562 of 2109]). Nearly all participants reported they were satisfied with their eyeglasses (98% overall, 99.0% free clinic, 97% at the FQHC). However, a small percentage reported they were dissatisfied (0.8% overall, 0.4% free clinic, 1.1% at the FQHC) or that their eyeglasses required a remake (1.3% overall, 0.6% free clinic, 1.7% at the FQHC).

In the initial cohort, 59% of participants screened negative for pathology and had follow up recommended according to age-related guidelines, which were all >1 year (2208 of 3714). Those who screened positive for pathology were considered a high-risk referral and were recommended for follow up in ≤ 1 year (41%, 1506 of 3714). At the end of study period, 72% of participants who were high-risk referrals (1084 of 1506) had 1 year elapse since follow-up recommendations were given. Information on attendance at recommended follow-up with an ophthalmologist within that year was obtained on 783 of these participants, of whom 529 (68%) attended follow-up. Assuming those who we were unable to obtain follow-up information on were non-adherent, the rate of attending recommended follow-up could be as low as 49% (529 of 1084). Follow-up attendance was also obtained on the subset of glaucoma participants included in the randomized trial (Supplemental Table 2). A total of 490 participants were included in the trial and randomized to either care navigation plus personalized education and motivational-interviewing-based health coaching ($n=247$) or care navigation plus standard written education ($n=243$). Attendance at recommended follow-up was similar between groups (61% versus 59% respectively, $p=0.74$). No difference in attendance rates was observed when stratifying by site (77% vs 71% at the free clinic, $p=0.35$; 51% vs 53% at the FQHC, $p=0.82$), although overall adherence to recommended follow-up was higher at the free clinic than at the FQHC.

Costs of the program were assessed from both a macro perspective and a micro perspective. First year study costs were previously reported and included both non-recurring startup costs (\$206,369.27) and first year costs for labor and supplies (\$496,206.09), excluding research costs.¹⁸ We updated startup costs to amortize the cost of the OCT and other ophthalmology equipment over the study period (\$87,354.83) and updated yearly recurrent costs to exclude rent costs and reflect the reduced costs of office supplies and clinician oversight time (\$393,261.59). Therefore, from a macro perspective, the cost of the program over the 3–3.5 year study period was \$1,410,318.97, with a cost per participant served of \$379.73, cost per case of pathology detected of \$707.28, and a cost per case of glaucoma/suspected glaucoma detected of \$1,695.09. In the micro-cost analysis where we used time studies to calculate the cost of the telemedicine based glaucoma screening as if it were an add-on to the infrastructure of an existing eye clinic,²³ the clinical costs were \$344,831.28 (ophthalmic technician time for the screenings cost of \$289,645.64 plus ophthalmologist time to review the screenings cost of \$55,185.64). The equipment and supply costs for the 3.5 years was \$67,370.02. Therefore, the entire program had a cost per participant served ($n=3714$) of \$110.99, cost per case of any pathology detected ($n=1994$) of \$206.72, and cost per case of glaucoma/suspected glaucoma detected ($n=832$) of \$495.43.

Discussion

The MI-SIGHT program screened 3,714 people for glaucoma and other eye disease over 3.5 years. The MI-SIGHT participants, recruited from a free clinic and FQHC, had higher rates of poverty compared to poverty rates in the US overall, with 63.5% having a household income less than \$30,000/year compared to 25.2% of US households earning less than \$35,000 per year in 2022.³² Disparities in eye health outcomes have been well documented among people with lower socio-economic status, who are disproportionately comprised of Black, African American, Latinx, and Indigenous people.³³ Placing the glaucoma and eye disease screening program in community clinics that serve people with low income enabled people who might not otherwise access specialty eye care services to receive an eye disease screening exam and low cost, affordable eyeglasses. The program identified five times the national rate of visual impairment, 1.8 times the national rate of uncorrected refractive error, 1.3 times the national rate of cataract, 1.4 times the rate of diabetic retinopathy, and 1.8 times the national rate of definite glaucoma. The observed high rate of glaucoma/suspected glaucoma of 22.4% is similar to the 25% screen positive rate observed in all three SIGHT studies combined at community locations in New York City, rural Alabama, and in the Michigan-SIGHT program. With such a high screen-positive rate for glaucoma/suspected glaucoma, the positive predictive value for bringing a SIGHT patient in for further ophthalmic examination was calculated at 86% and the false discovery rate at 14%, which would put many fewer people at risk of overtreatment and help many more people gain access to appropriate management and treatment.³⁴ People were highly satisfied with the MI-SIGHT Program and the glasses from the MI-SIGHT Program. Moreover, the MI-SIGHT Program improved outcomes. Participants vision improved because they had access to affordable glasses that were cosmetically appealing enough that participants were wearing them when they returned for their repeat screening. Participants vision-related quality of life improved, perhaps because they could see better with their affordable glasses, or perhaps because they were less worried about their eye health.

The overall rate of attendance at recommended follow-up appointments to close the loop on screening and obtain definitive care were reasonable at 68% compared to prior screening studies, where follow-up rates have ranged from 36%³⁵ to 61%³⁶ with some of the variation likely due to different program structures. Within our randomized controlled trial comparing care navigation and written information to care navigation and personalized education and motivational-interviewing based health coaching to improve attendance and recommended follow-up for those who screened positive for glaucoma, we did not find a significant difference in attendance (61% vs 60%). However, both groups did receive high levels of care navigation and both groups had reasonably high follow-up attendance rates compared to prior work evaluating follow-up rates after screening programs.^{35–39}

The MI-SIGHT program took place in two primary care clinics who serve people with low-income, a free clinic and an FQHC. Free clinics are highly variable in both the services they are able to provide and the volume of people they are able to care for, as these services depend on donations and volunteers for sustainability. FQHCs can bill, on a fee-for-service basis, for the medical services provided, and so increasing the volume of services rendered also increases the revenue for the FQHC, making FQHCs a potentially

sustainable partner in scaling the provision of eye disease screening and optical services for medically underserved people in the United States. Currently, FQHCs are funded under Section 330 of the Public Health Service Act, which provides federal funding to offset costs of uncompensated care and aid in securing malpractice coverage for FQHCs whose mandate is then to provide primary care to medically underserved populations.⁴⁰ FQHCs predominantly provide care to people insured by Medicaid and to people who are uninsured. To make this financially sustainable, FQHCs receive a flat rate for each health care visit provided from the Prospective Payment System, a rate which is often slightly higher than the Medicaid rate for the same service in that state (\$178/visit in 2021, Sherry Pace, former COO Hamilton Community Health Network, personal communication). Because telemedicine for eye care is not currently a reimbursed service at the FQHC in Michigan, no revenue was generated for the clinic from the telemedicine services provided by MI-SIGHT. If the program had been delivered by FQHC eye doctors who gave the screening results in person and confirmed these results with a slit lamp exam, they could have billed the PPS rate under CPT code G0117 for glaucoma screening for patients who 1. Had a family history of glaucoma, or 2. Identified as African American and were $\geq$ age 50; or 3. Identified as Hispanic or Latino and were $\geq$ age 65; or 4. Had diabetes or for patients who had any other ocular pathology.

Though FQHCs are often the medical home for many people insured by Medicaid and people without insurance, and provide care for 1 in 11 Americans, they are mostly not equipped to provide eye care. In 2021, only 2.6% of people accessing medical care at FQHCs received eye care, and 76% of FQHCs provided no form of eye care services, not even diabetic retinopathy screening.⁴¹ The eye care provided at FQHCs is largely concentrated in three states, with California, New York, and Massachusetts employing 56% of eye doctors at FQHCs nationally.⁴² Access to eye care is limited outside of FQHCs for people who are uninsured and even those with Medicaid. One study found that people with Medicaid, compared to those with private insurance, had 60% decreased odds of obtaining an appointment with an eye doctor when they called to schedule.⁴³ Within FQHCs, resources to help people with limited income access needed services are robust. The 1,385 FQHCs nationwide employ 5,086 full-time social workers to help with transportation and social services to support access to care.⁴² FQHCs are uniquely poised to provide direct eye disease screening, primary eye care and vision services including glasses, and help accessing recommended specialty eye care.

The MI-SIGHT program offers a paradigm for implementing eye disease screening, optical care, and eye care navigation in FQHCs that has high satisfaction, successfully detects eye disease, and resulted in improved vision and vision-related quality-of-life. It is a program that has set guidelines, based on the Veterans' Affairs Technology Based Eye Care Services standards, for when to refer a person for eye care with a doctor.¹⁹ The protocol is based in ophthalmologists grading a standard set of history, measurements, and images and making recommendations for care, which are then communicated by ophthalmic technicians who are employed locally in the community clinic. Other eye disease screening models range from having an optometrist or ophthalmologist examine each patient with a biomicroscope to the future potential of having a medical assistant take an image of the retina and having an artificial intelligence algorithm assess for any referable pathology.⁴⁴ Current workforce

shortages projected for ophthalmologists⁴⁵ mean that a team-based approach to providing eye disease screening and optical correction is needed, where more ophthalmologist time is spent with people who have ophthalmic disease rather than spending equal amounts of time with those who do and do not have disease.

The costs of the MI-SIGHT program to detect a case of eye disease ranged from \$379.73 from a macro-costing perspective to \$206.72 from a micro-costing perspective. When comparing the micro-costing analyses, the cost per participant served and per case of eye disease detected was similar to the NYC-SIGHT program (\$110.99 for MI-SIGHT vs \$180.88 for NYC-SIGHT per participant served; \$206.72 for MI-SIGHT vs \$273.64 for NYC-SIGHT per case of eye disease detected).²³ NYC-SIGHT offered eye disease screening in low-income housing and low-income senior centers where people were screened by community health workers for presenting visual acuity, intraocular pressure, and had non-dilated fundus photos taken of the nerve and macula. Then, participants with vision of 20/40 or worse, IOP 23 mmHg or higher, or pathology on fundus exam were scheduled to see an on-site optometrist free-of-charge within 3 weeks. This program randomized people to receiving donated glasses free of charge or a glasses prescription, where the MI-SIGHT program leveraged a low-cost online glasses retailer to provide glasses for all participants. Both represent novel ways of bringing eye disease screening into medically underserved communities. However, currently, neither low-income housing developments nor FQHCs have the funds or resources to support this service. However, a few policy changes could make eye disease screening and optical care possible at FQHCs: 1) National Health Service Corps loan repayment would need to be opened up for eye doctors, either optometrists or ophthalmologists, to incentivize working at FQHCs, where salaries are lower and there are high no-show rates that lead to lower revenues, and there is no revenue stream from an optical shop. 2) Block grants would need to be made for the ophthalmology equipment as current fee-for-service flat rates that do not include additional coverage for ancillary testing preclude FQHCs from purchasing equipment needed for high quality screening, such as OCT. 3) Reimbursement would need to be allowed for telemedicine for eye disease screening in general, not just for diabetic retinopathy screening. 4) Medicaid fee structures would need to be augmented in some way so that participants screening positive for disease at the FQHC would be able to get definitive care from community ophthalmologists while enabling community ophthalmologists to sustain their practice. Placing eye disease screening, optical care, and care navigation in FQHCs could represent a way to mitigate the persistent disparities in eye health in the United States.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Funding:

Financial Support:

This work was supported by the Centers for Disease Control and Prevention (Atlanta, GA; U01DP0064420100, PANC, ARE, MAW, LMN, AKB, RR, SW), National Institute for Minority Health and Health Disparities (Bethesda, MD; K23MD016430, ARE), and Research to Prevent Blindness (Physician Scientist Award, PANC, Career Advancement Award, MAW), and the University of Michigan Clinical and Translational Science Award

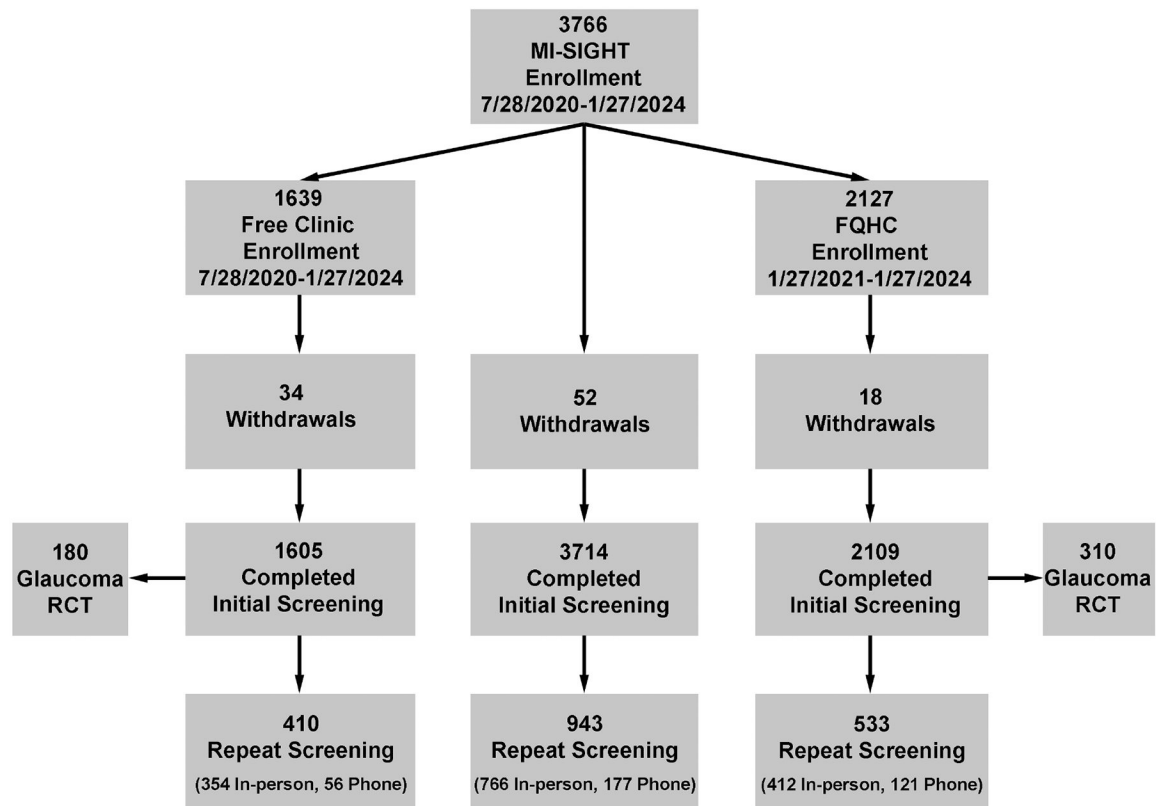
(UM1TR004404). The funding organizations had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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Level1=Glaucoma&Level2=Glaucoma+Prevalence&Level3=Diagnosed+Glaucoma,+Any+Type&Level4=Diagnosed+Glaucoma-Any+Stage&LocationId=26&DataSourceId=MEDICARE&IndicatorId=QDXDC5~R5_ALL&ShowFootnotes=true&View=StateChartTable&CompareViewYear=1&CompareId=&CompareId2=&YearId=YR11&ResponseId=R5_ALL&AgeId=AGEALL&GenderId=GALL&RaceId=ALLRACE&RiskFactorId=RFALL&RiskFactorResponseId=RFTOT&DataValueTypeId=CRDPREV&MapClassifierId=quantile&MapClassifierCount=4&CountyFlag=N
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**Figure 1.**

Flow chart of MI-SIGHT program participants

MI-SIGHT, Michigan Screening & Intervention for Glaucoma and Eye Health through Telemedicine; FQHC, Federally Qualified Health Center; RCT, Randomized Controlled Trial

Table 1.

Characteristics of participants in the MI-SIGHT program (n=3714)

Continuous Variable	Overall (n=3714)			Free Clinic (n=1605)			FQHC (n=2109)			Raw P-value *	Holm P-value
	N	Mean (SD), Median		N	Mean (SD), Median		N	Mean (SD), Median			
Age (years)	3714	54.1 (15.9), 56.3		1605	54.5 (15.9), 56.8		2109	53.8 (15.9), 55.9		0.2199	0.9522
Presenting LogMAR VA - Better Eye	3711	0.13 (0.22), 0.00		1604	0.11 (0.23), 0.00		2107	0.14 (0.22), 0.04		<0.0001	<0.0001
Categorical Variable		#/total (%)			#/total (%)			#/total (%)		Raw P-value *	
Sex - Male		1377/3677 (37.5)			582/1584 (36.7)			795/1298 (38.0)		0.4412	0.9522
Race											
White		1085/3413 (31.8)			586/1487 (39.4)			499/1926 (25.9)			
Black		1775/3413 (52.0)			544/1487 (36.6)			1231/1926 (63.9)			
Asian		187/3413 (5.5)			175/1487 (11.8)			12/1926 (0.6)			
Other/Multiracial		366/3413 (10.7)			182/1487 (12.2)			184/1926 (9.6)			
Ethnicity - Hispanic		608/3197 (19.0)			233/1306 (17.8)			375/1891 (19.8)		0.1587	0.9522
Education											
<HS		363/3649 (10.0)			163/1563 (10.4)			200/2086 (9.6)			
HS or Equivalent		1171/3649 (32.1)			405/1563 (25.9)			766/2086 (36.7)			
Some College		1114/3649 (30.5)			430/1563 (27.5)			684/2086 (32.8)			
College Degree		605/3649 (16.6)			334/1563 (21.4)			271/2086 (13.0)			
Graduate/Professional Degree		396/3649 (10.9)			231/1563 (14.8)			165/2086 (7.9)			
Income											
<\$10k		632/2829 (22.3)			307/1198 (25.6)			325/1631 (19.9)			
\$10k-\$19,999		595/2829 (21.0)			251/1198 (21.0)			344/1631 (21.1)			
\$20k-\$29,999		570/2829 (20.2)			251/1198 (21.0)			319/1631 (19.6)			
\$30k-\$49,999		562/2829 (19.9)			200/1198 (16.7)			362/1631 (22.2)			
\$50k-\$69,999		240/2829 (8.5)			86/1198 (7.2)			154/1631 (9.4)			
\$70k+		230/2829 (8.1)			103/1198 (8.6)			127/1631 (7.8)			
Unemployed/Retired/Disable/Homemaker/Student		2134/3659 (58.3)			933/1567 (59.5)			1201/2092 (57.4)		0.1957	0.9522
No Health Insurance		865/3630 (23.8)			628/1549 (40.5)			237/2081 (11.4)		<0.0001	<0.0001
Primary Language not English		747/3693 (20.2)			400/1595 (25.1)			347/2098 (16.5)		<0.0001	<0.0001

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Self-reported Medical History				
Diabetes	880/3616 (24.3)	305/1548 (19.7)	575/2068 (27.8)	<0.0001
Hypertension	1636/3598 (45.5)	615/1532 (40.1)	1021/2066 (49.4)	<0.0001
Current Smoker	632/3671 (17.2)	189/1576 (12.0)	443/2095 (21.2)	<0.0001
Self-reported Glaucoma	152/3039 (5.00)	65/1216 (5.4)	87/1823 (4.8)	0.4777
Family History Glaucoma	771/3039 (25.4)	293/1216 (24.1)	478/1823 (26.2)	0.1872
Last dilated eye exam > 2 year/Never	1788/2940 (60.8)	802/1246 (64.4)	986/1694 (58.2)	0.0007

MI-SIGHT, Michigan Screening & Intervention for Glaucoma and Eye Health through Telemedicine; FQHC, Federally Qualified Health Center; SD, Standard Deviation; VA, Visual Acuity; HS, High School; k, \$1000

* p-value testing site differences, including 2-sample t-test (age), 2-sample Wilcoxon test (presenting logMAR VA), Chi-square tests (categorical variables with cell counts >5), and Fisher's exact tests (categorical variables with cell counts <5)

^a Post-hoc pairwise comparisons showed that free clinic had a significantly larger percentage of White (p<0.0001), Asian (p<0.0001), and Other/Multiracial (p=0.0119) participants, but a significantly smaller percentage of Black participants (p<0.0001) than the FQHC.

^b Post-hoc pairwise comparisons showed that free clinic had a significantly smaller percentage of participants with a high school education (p<0.0001) or some college (p=0.0006), but a significantly larger percentage of participants with a college degree (p<0.0001) or graduate education (p<0.0001) than participants at the FQHC.

^c Post-hoc pairwise comparisons showed that the free clinic had a significantly larger percentage of participants who reported income of <\$10k (p=0.0003), but a significantly smaller percentage of participants who reported income of \$30k-\$49,999 (p=0.0003) or \$50k-\$69,999 (p=0.0328) than participants at the FQHC.

Table 2.
Clinical screening results for participants of the MI-SIGHT program (n=3714)

Screening Variable	Overall (n=3714)	Free Clinic (n=1605)	FQHC (n=2109)
	n/N (%)	n/N (%)	n/N (%)
Glaucoma/Glaucoma Suspect	832/3709 (22.4)	344/1600 (21.5)	488/2109 (23.1)
Macular Degeneration	64/3714 (1.7)	22/1605 (1.4)	42/2109 (2.0)
Diabetic Retinopathy	170/3624 (4.7)	55/1565 (3.5)	115/2059 (5.6)
Cataract	798/3484 (22.9)	395/1598 (24.7)	403/1886 (21.4)
Not Visually Significant	580	265	315
Visually Significant			
Cataract	218	130	88
Visual Impairment (Better Eye <20/40)	426/3705 (11.5)	153/1602 (9.6)	273/2103 (13.0)
Visual Impairment (Either Eye <20/40)	989/3707 (26.7)	358/1602 (22.4)	631/2105 (30.0)
Un- or Under-Corrected RE	345/3703 (9.3)	102/1602 (6.4)	243/2101 (11.6)
Other pathology *	560/3714 (15.1)	259/1605 (16.1)	301/2109 (14.3)

MI-SIGHT, Michigan Screening & Intervention for Glaucoma and Eye Health through Telemedicine; FQHC, Federally Qualified Health Center; RE, Refractive Error

* See Supplemental Table 1

Table 3. Change in vision and vision-related quality of life for the subset of MI-SIGHT participants who returned for a repeat screening (n=943)

Variable	Initial Screening		Repeat Screening		Holm P-value*
	n	mean (SD), median	n	mean (SD), median	
Overall (n=766 VA, 943 VFQ)					
Presenting logMAR VA - Better Eye**	762	0.09 (0.16), 0.00	762	0.09 (0.17), 0.00	0.1809
Presenting logMAR VA - Worse Eye**	763	0.25 (0.59), 0.10	763	0.21 (0.52), 0.06	0.0012
Composite	937	81.1 (14.1), 83.9	937	86.4 (12.0), 89.4	<0.0001
General Vision	930	70.8 (17.3); 80.0	930	74.9 (16.5), 80.0	<0.0001
Near Activities	933	81.0 (18.3), 83.3	933	88.6 (15.4), 91.7	<0.0001
Distance Activities	905	86.7 (20.3), 100.0	906	91.5 (17.7), 100.0	<0.0001
Mental Health	928	60.6 (29.1), 50.0	928	64.9 (30.4), 75.0	0.0001
Role Difficulties	920	88.8 (24.7), 100.0	920	93.2 (20.3), 100.0	<0.0001
Driving	844	92.5 (16.4), 100.0	844	95.6 (13.5), 100.0	<0.0001
Peripheral Vision	919	90.1 (17.6), 100.0	91	93.5 (14.8), 100.0	<0.0001
Free Clinic (n=354 VA, 410 VFQ)					
Presenting logMAR VA - Better Eye**	351	0.06 (0.25), 0.00	351	0.07 (0.17), 0.00	0.2610
Presenting logMAR VA - Worse Eye**	353	0.20 (0.59), 0.00	353	0.19 (0.58), 0.02	0.8996
Composite	404	79.8 (14.6), 81.7	404	85.1 (12.4), 88.9	<0.0001
General Vision	400	69.1 (17.9), 80.0	400	76.7 (16.5), 80.0	<0.0001
Near Activities	401	79.7 (18.6), 83.3	401	86.5 (15.4), 91.7	<0.0001
Distance Activities	396	85.4 (20.6), 100.0	396	89.0 (19.4), 100	0.0058
Mental Health	404	60.6 (27.1), 50.0	404	66.6 (27.1), 75.0	0.0001
Role Difficulties	400	86.5 (25.8), 100.0	400	89.4 (24.5), 100.0	0.2151
Driving	357	91.9 (16.1), 100.0	357	94.0 (16.1), 100.0	0.1388
Peripheral Vision	396	88.5 (18.1), 100.0	396	91.5 (16.6), 100.0	0.0163
FQHC (n=412 VA, 533 VFQ)					
Presenting logMAR VA - Better Eye**	411	0.11 (0.17), 0.00	411	0.11 (0.17), 0.02	0.6158
Presenting logMAR VA - Worse Eye**	410	0.29 (0.59), 0.18	411	0.23 (0.46), 0.10	0.0004
Composite	533	82.1 (13.6), 84.4	533	87.4 (11.6), 90.0	<0.0001
General Vision	530	72.0 (16.7), 80.0	530	73.6 (16.3), 80.0	0.1580

Variable	Initial Screening			Repeat Screening			Holm P-value*
	n	mean (SD), median	n	mean (SD), median	n	mean (SD), median	
Near Activities	532	81.9 (18.0), 83.3	532	90.1 (15.2), 100.0			<0.0001
Distance Activities	509	87.7 (20.0), 100.0	509	93.4 (16.0), 100.0			<0.0001
Mental Health	524	60.6 (30.5), 50.0	524	63.5 (32.5), 75.0			0.1542
Role Difficulties	520	90.5 (23.8), 100.0	520	96.1 (15.7), 100.0			<0.0001
Driving	487	93.0 (16.5), 100.0	487	96.8 (11.1), 100.0			<0.0001
Peripheral Vision	523	91.3 (17.2), 100.0	523	95.0 (13.1), 100.0			<0.0001

MI-SIGHT, Michigan Screening & Intervention for Glaucoma and Eye Health through Telemedicine; SD, Standard Deviation; VA, Visual Acuity; FQHC, Federally Qualified Health Center; VFQ, Visual Function Questionnaire

* P-value testing change between initial and repeat screenings, including Wilcoxon signed rank test (presenting logMAR VA) and paired t-tests (VFQ scales)

** Better or Worse eye chosen at initial screening; if both eyes presented the same, the one that had the smallest change at repeat screening was considered the better eye and the one with the largest change at repeat screening was considered the worse eye