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Detection of Eye Diseases and Referral Rates for In-Office Eye Care Across Three SIGHT Studies

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Abstract

Purpose: To report eye disease detection referral rates for in-office eye care across the Screening and Intervention for Glaucoma and eye Health through Telemedicine (SIGHT) Studies conducted in Alabama (AL-SIGHT), Michigan (MI-SIGHT), and New York City (NYC-SIGHT).

Methods: Individuals age ≥ 40 years who completed eye health screenings in federally qualified health centers, a free clinic, and affordable housing developments were included in the analysis. Visual acuity, intraocular pressure (IOP), and fundus photography were conducted across all sites and detection of eye diseases and referral rates are reported. Two-sample t-test and chi-square test (or Fisher's exact test) were used to compare continuous and categorical variables, respectively, between those referred and not referred.

Results: Of the 838 participants screened in AL-SIGHT, 2970 in MI-SIGHT, and 708 in NYC-SIGHT, referral rates for in-office eye care were 47.3%, 42.8%, and 66.1% respectively. Detection rates of glaucoma and glaucoma suspect in AL-SIGHT were 18.6%, MI-SIGHT were 24%, and NYC-SIGHT were 26.7%. Among those referred there were significantly more participants

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who identified as Black race, had high school or less education, were single/divorced/separated/widowed, retired or unable to work/disabled, insured with Medicare, or reported having diabetes, hypertension, or glaucoma ($p < 0.05$).

Conclusion: The SIGHT Studies provide evidence that reaching underserved individuals at high-risk for eye diseases and providing telehealth-based eye health screenings in trusted community-based settings, led to high rates of eye disease detection and referral for in-office eye care.

Keywords

Community-based eye health screening; eye disease detection; referral for in-office eye care; SIGHT Studies; social determinants of health

Introduction

Over 13 million Americans are living with vision impairment or blindness.^{1,2} Glaucoma, diabetic retinopathy (DR), cataracts, and age-related macular degeneration (AMD) are the leading causes of blindness in the United States (US), and prevalence rates are increasing as the population ages.³ A disproportionate burden of eye diseases currently exists among minority and underserved populations, for example, Black and Hispanic individuals are more likely to experience vision problems, have lower rates of eye care utilization and have greater odds (roughly 4.4 times and 2.5 times, respectively) of having undiagnosed glaucoma compared to non-Hispanic White individuals.^{4–8} Minorities are disproportionately represented among people living with lower-socio-economic status and are more likely to have both vision impairment and glaucoma.^{9–12} Social determinants of health (SDOH), which are the conditions in which people are born, grow, work, live, and age, affect health risks and outcomes.¹³ Five key areas for improving SDOH are: (1) healthcare access and utilization; (2) education; (3) economic stability; (4) neighborhood and built environment; and (5) social and community context and must be considered to address these eye health disparities.^{13,14} Innovative and effective interventions that focus on communities with high social inequality are needed to address barriers, reduce eye health disparities, and prevent permanent vision loss and blindness among millions of Americans who are less likely than other groups to obtain proper and recommended eye care.^{15–18} Tele-ophthalmology can bridge the gap between patient and provider and present a unique opportunity to diminish travel time and financial burden for individuals who are unable to seek eye care in traditional in-office settings. To this end, the Centers for Disease Control and Prevention's (CDC) Vision Health Initiative funded three research studies from 2019 to 2024, which aimed to reach and engage individuals at higher risk for glaucoma and other eye diseases.¹⁴ The *Screening and Interventions for Glaucoma and eye Health through Telemedicine* (SIGHT) Studies were conducted in rural Alabama (AL-SIGHT), Michigan (MI-SIGHT), and New York City (NYC-SIGHT), and the recruitment methods and study designs have been previously published.^{19–22} One of the aims for the CDC in creating an overarching vision of how to screen for glaucoma in high-risk populations across three different locations was to compare how different strategies and different geographies were able to carry out this central mission. To accomplish this, the CDC created a Coordinating Center to serve as a general

organizing body, determine common variables for data collection, coordinate comparison of programs and outcomes across sites, and disseminate findings. This paper reports eye disease detection rates and referral rates for in-office eye care between the three SIGHT Studies, highlighting the differences and similarities between the programs, and lays out future directions for how to improve the rigor with which we go about glaucoma screening.

Materials and methods

Study design

The SIGHT Studies used recruitment materials, clinical protocols and manual of procedures approved by their Institutional Review Boards (IRBs) (University of Alabama at Birmingham IRB300004921; University of Michigan IRB00000244, and Columbia University IRB-AAAR9162). The IRBs at Columbia University and Westat approved their coordinating center function (Columbia University IRB-AAAT0194; Westat IRB/FWA #00005551) to collect and synthesize deidentified data. All aspects of the study were conducted in accordance with the Declaration of Helsinki and compliance with Health Insurance Portability and Accountability Act (HIPAA).

Recruitment locations

In order to reach high-risk individuals living at or below the poverty level, recruitment and eye health screenings were conducted from 2020 to 2023.¹⁹ The AL-SIGHT team partnered with three FQHCs in rural areas to recruit eligible participants and conducted screenings in these health centers.²⁰ The MI-SIGHT study team partnered with two community-based healthcare facilities, a free clinic, and a FQHC, and recruited eligible participants and conducted screenings in these clinics.²¹ The NYC-SIGHT study team partnered with the NYC Housing Authority and the NYC Department for the Aging to recruit and conduct eye health screenings in community centers and senior centers located where people live in Harlem and Washington Heights neighborhoods.^{22,23}

Inclusion criteria

AL-SIGHT: Individuals who were (1) African American or Hispanic ≥ 40 years of age; (2) White ≥ 50 years of age; (3) anyone ≥ 18 years of age with diabetes, (4) anyone ≥ 18 years of age with a glaucoma-associated diagnosis, and (5) anyone ≥ 18 years of age with a family history of glaucoma.

MI-SIGHT: Individuals who were (1) ≥ 18 years of age with diabetes mellitus, (3) African-Americans ≥ 40 years of age, (4) Latinos ≥ 60 years of age, (5) Caucasians ≥ 65 years of age, and (6) persons from all ethnic backgrounds with a family history of glaucoma.

NYC-SIGHT: Individuals who were (1) ≥ 40 years of age, and (2) living independently in affordable housing developments or a member of the senior center.

Across all sites, those who met the study's inclusion criteria were consented over the telephone or in person. Only enrolled participants age 40 and older were included in this analysis.

Demographics and social determinants of health indicators

Participants completed a survey prior to the screening and reported their date of birth, sex, race/ethnicity, education level, health insurance, employment, marital status, and transportation methods to medical appointments.

Clinical characteristics and access to eye care

Medical and ocular conditions, prescription eyeglasses use, and family history of glaucoma and blindness were asked. Participants were asked if they ever had a dilated eye exam and if so, approximately when was their last dilated eye exam. Participants who had not had a recent dilated eye exam were asked for the main reason for not attending.

Eye disease detection methods by location

Methods used to detect eye diseases across the SIGHT Studies are described below, including the similarities and differences Table 1 and have been previously published.^{20–22}

Visual acuity: Presenting distance visual acuity was measured in all SIGHT Study participants by trained study staff using the Snellen eye chart while participants wore their current eyeglasses (with correction). Methods and criteria for each site have been previously published.^{20–22}

Intraocular pressure (IOP): The IOP was measured in both eyes in all SIGHT Study participants by trained staff using the TA01I Icare rebound tonometer (ICare, Helsinki, Finland). If the IOP measured 23–29 mmHg, they were referred to the study optometrist. If IOP was ≥ 30 mmHg, participants were given a referral with an eye care provider within 2 weeks. If the IOP was ≥ 35 mmHg, a referral was made within 1 week. If the IOP was ≥ 40 mmHg, participants were given an urgent referral within 1 day.

Central corneal thickness (CCT): CCT was measured by pachymetry (Pachmate 2, DGH Technology, Exton, PA) at MI-SIGHT.

Fundus photography and optical coherence tomography (OCT) by location

AL-SIGHT fundus photography/OCT: Structural and functional assessment of the optic nerve and fundus was assessed through undilated pupils using an SD-OCT and a fundus camera (Maestro 2, Topcon Medical Systems, NJ). Fundus images of the optic nerve and macula of both eyes were obtained with the Maestro 2 device. The optic nerve was also functionally assessed through perimetry testing with a Humphrey Field Analyzer screening strategy SITA-FAST (Carl Zeiss Meditec, California).²⁴ The remote ocular assessment (ROA) data was used to create reports, recommend treatment course and frequency of follow-up to the study participant and the physician on site. Overall determination was made for each eye as (1) normal or abnormal without significant findings, (2) abnormal with significant findings, or (3) unreadable.²⁰

MI-SIGHT external photography/fundus photography/OCT: The ophthalmic technician at the community clinic used 0.5% Tropicamide to dilate all participants without a narrow angle on penlight exam and IOP ≤ 30 mmHg to mitigate the potential risk of acute

angle closure.²⁵ The ophthalmic technician then imaged the posterior pole of each eye by fundus photography (one image each of the disc, macula, and supertemporal arcade), one external photograph of each eye, and OCT of the macula and retinal nerve fiber layer of each eye (Topcon Maestro 2, Topcon Medical Systems, NJ). The remote ophthalmologists designated whether each type of imaging for each eye was: (1) normal without significant findings, (2) abnormal with significant findings, or (3) unreadable.²¹

NYC-SIGHT fundus photography: Two posterior fundus images of each eye were taken by a trained ocular photographer using the non-mydratic, autofocus, hand-held fundus camera (Volk Pictor Prestige; Volk Optical, Mentor, OH) and remotely read and graded by two study ophthalmologists specializing in glaucoma and retina. Overall determination was made for each eye as (1) normal or abnormal without significant findings, (2) abnormal with significant findings, or (3) unreadable.²²

Refraction: Refraction measurements were taken at all sites using an autorefractor (NYC- and AL-SIGHT: Plenoptika, MI-SIGHT: Autorefractor and Keratometer ARK, Marco Ophthalmic, Jacksonville, FL). In MI-SIGHT, the auto-refraction was refined using manifest refraction with a phoropter, and in NYC and Michigan, the prescription was tested in trial frames.

Criteria for referral to in-office eye care

AL-SIGHT referral: Based on structural and functional optic nerve testing and review of the clinical data, the ophthalmologist, who reviewed the images remotely, defined the participant as normal, glaucoma suspect, ocular hypertensive, glaucoma, or other abnormality, according to the *American Academy of Ophthalmology's (AAO) Preferred Practice Guidelines*.^{®26,27} In participants who had glaucoma suspect status, ocular hypertension, or glaucoma, the recommendation was a referral for in-office eye care with a community-based optometrist who works with the FQHC, or with an ophthalmologist at the Glaucoma Service at University of Alabama at Birmingham (UAB), or the Lions Eye Clinic at UAB. Depending on the eye diseases identified, the participant was contacted for an in-office referral appointment to either the community-based optometrist or UAB ophthalmologist. Participants found to have significant refractive error, from the autorefraction performed by the coordinator, were referred to the community optometrist's office for manifest refraction and glasses prescription. Those with or without health insurance received eye care through UAB by the same ophthalmologist.

MI-SIGHT referral: Ophthalmologists remotely assessed whether the following vision and eye diseases were present or absent using a template in the electronic health record (EHR): best corrected visual acuity (BCVA) $\leq 20/40$ in the better seeing eye, high myopia $\geq -5.0D$, high hyperopia $\geq +5.0D$, high astigmatism $\geq +3.0D$, visually significant cataract requiring surgery, glaucoma/suspected glaucoma, AMD, and DR, alongside any other incidental findings using standard guidelines.^{21,26} If a participant screened positive for any eye disease requiring an in-office eye care referral, the timeline was based on the ophthalmologists' judgement after their review of the abnormal findings based on *AAO Practice Pattern Guidelines*.^{®26,27}

NYC-SIGHT referral: After the two ophthalmologists remotely read all fundus/optic nerve images, participants who had any abnormal image findings were referred to ophthalmology for in-office eye care. Participants were diagnosed with glaucoma, glaucoma suspect, cataract, retinal abnormalities, or other ocular diagnoses by the study optometrist using the *AAO Practice Pattern Guidelines*,[®] and were also referred for in-office eye care.^{26,27} The criteria for referral by the optometrist also included those participants who had not received a dilated eye exam within the last two years, could not remember their last eye exam, or never had an eye exam. All referred participants were scheduled for their initial in-office comprehensive eye exam appointment within 6 months of the eye health screening by the study staff.²⁸ Diabetic retinopathy rates were based on total screened population to account for undiagnosed cases of diabetic retinopathy.

Confirming in-office eye exam attendance

In AL-SIGHT Study, the FQHC staff was notified of participants needing follow-up eye exam referrals and they scheduled all appointments and communicated this to the participant; this information was also communicated to the study coordinator who kept in contact with the participant to facilitate making reminders to attend appointments. The coordinator tracked appointment adherence at the optometrist's or ophthalmologist's office. Participants who were "no-shows" to appointments were scheduled for new appointments for a period of up to six months. The coordinator documented the participant's appointment adherence for a period of six months by remaining in contact with all clinics where participants were referred.

In MI-SIGHT Study, the ophthalmic technicians who conducted the remote telemedicine assessment also functioned as health educators and care navigators. After the remote ophthalmologist graded the data and gave follow-up recommendations, participants returned for a second visit with the ophthalmic technician. At that second visit, the ophthalmic technician dispensed the glasses from the on-line retailer and ensured a proper fit, educated the participants about the doctor's findings and recommendations, and assisted the patient in making the appropriate follow-up appointment. In addition, if a patient needed assistance with transportation, interpretation, or insurance, if the ophthalmic technician could not provide the assistance they helped connect the participant with a social worker or a community resource to provide the assistance.

In NYC-SIGHT Study, all eye exam dates were documented in the Research Electronic Data Capture (REDCap) and study staff reviewed EPIC electronic medical records (EMR) each time a participant was scheduled to document appointment adherence over 10 months.

Statistical analysis

The SIGHT Studies Coordinating Center received summarized data, including demographic, social determinants of health indicators, medical and ocular history, detection of eye diseases, and referred and not referred for in-office follow-up eye care from the three SIGHT Studies. The data were aggregated into a single database and analyzed separately by the coordinating center biostatistician. Only enrolled participants age 40 and older were included in this analysis.

Participant characteristics were compared between those referred and not referred for in-office eye care. A two-sample t-test and Fisher's exact test and chi-square test were used to compare continuous and categorical variables, respectively, between those referred and not referred stratified by site. p values of ≤ 0.05 (two-sided) were considered statistically significant. The R 4.4.0 statistical software and IBM Statistical Package for Social Science Version 28 (IBM Corp. Armonk, NY) (IBM SPSS Statistics for Windows Version 28.0. 2021) were used for data analysis.

Results

Eye diseases detected

For consistent data analysis across the three sites, only enrolled participants over age 40 are described and presented in Tables 2–4. SIGHT Studies screened 4,516 participants over age 40 and each location detected a substantial amount of eye disease requiring referral for in-office eye care [total referred: AL: (47.3%); MI: (42.8%); NYC: (66.1%)] Table 2. The highest rates of uncorrected refractive error (76.8%) and cataracts (45.9%) were seen at the AL-SIGHT Study. Glaucoma/glaucoma suspects, including ocular hypertension detection rates, ranged from 18.6% at AL-SIGHT, 24% at MI-SIGHT, and 26.7% at NYC-SIGHT Table 2, including those with pre-existing glaucoma.

Reasons for referral

AL-SIGHT enrolled 838 participants for screening. A large percentage (76.8%) had uncorrected refractive error with 83 (9.9%) having vision impairment in the better seeing eye, 148 (18.6%) with glaucoma associated diagnoses, 52 (7.1%) with diabetic retinopathy, and 19 (2.4%) with macular degeneration. Almost half of participants had cataract ($n = 375$, 45.9%).

MI-SIGHT included 2970 participants age 40+ in this analysis. Of these participants, 711/2970 (24%) were referred for glaucoma/suspected glaucoma, 160/2970 (5%) for diabetic retinopathy, 64/2970 (2%) for macular degeneration, 215/2970 (7%) for surgical cataract evaluation, and 471/2970 (16%) for other eye conditions (e.g. retinal abnormalities, corneal abnormalities, etc.); participants could have more than one reason for referral. Those with a screening result for glaucoma ($n = 2965$), 119 self-reported a previous diagnosis of glaucoma, 484 reported no prior glaucoma diagnosis, and 108 didn't answer the question; thus, the incident rate of glaucoma could be between 16.3% (484/2965) if we include only those who reported no prior history of glaucoma and 20.0% (484 + 108/2965) if we include both those who did not report a prior history of glaucoma and those who did not answer the question.

NYC-SIGHT: Of the 308 participants who had completed the eye exam, 218 were referred to ophthalmology and 257 were diagnosed with refractive error. Reasons for referral included: glaucoma/glaucoma suspect ($n = 51$), cataracts ($n = 74$), retinal abnormalities ($n = 17$), other ocular diagnosis ($n = 22$), and no dilated eye exam in at least 2 years, could not remember their last eye exam, or never had an eye exam ($n = 103$). Based on telemedicine image data from the worse eye of those referred to ophthalmology, 250 participants had an

abnormal image, 138 were referred for an in-office glaucoma evaluation due to an abnormal optic disc image, and those with pre-existing glaucoma were excluded.

Characteristics of referred participants

Although the referral criteria varied between the three SIGHT Studies, as shown in Table 1, all sites used visual acuity, IOP measurements, and fundus/optic nerve photography as criteria for referrals. AL-SIGHT and MI-SIGHT also used OCT results. Participants across all sites with an IOP ≥ 23 mmHg, and/or an abnormal fundus image, read and confirmed by an ophthalmologist, were referred. The NYC-SIGHT Study optometrist also referred participants who failed the eye health screening and had not had an eye exam within 2 years for an in-office eye exam, as recommended by the Data Safety and Monitoring Board.

Mean age was significantly higher across all sites for those referred to in-office eye care compared to those who were not referred and ranged from age 62 (AL) to age 70 years (NYC) Table 3. Significantly higher referral rates were noted for participants age 60–79 years and ≥ 80 years at NYC-SIGHT ($p < 0.001$) and > 80 years at MI-SIGHT ($p < 0.001$) compared to those age 40–59 years Table 3. There were no significant differences in referral rates seen between men and women across the sites. In NYC-SIGHT, participants who were employed, unemployed, retired, or unable to work ($p < 0.030$) or had Medicare insurance had higher referral rates for in-office eye care compared to those who were not referred ($p = 0.002$). The majority of participants across all sites had health insurance Table 3. No other statistically significant differences were seen between those referred and not referred with regard to SDOH.

Medical and ocular history indicators related to referral

Higher referral rates were seen in participants who self-reported diabetes across all locations (AL: 50.4%; MI: 53.8%; NYC: 73.3%) Table 4. In both MI-SIGHT ($p < 0.001$) and NYC-SIGHT ($p < 0.027$), self-reported hypertension rates were higher among those referred compared to those not-referred. Referral rates for participants who self-reported having glaucoma were higher in MI-SIGHT and NYC-SIGHT ($p < 0.001$). At AL-SIGHT, participants who reported their last dilated eye exam more than 2 years ago ($p < 0.001$) and at MI-SIGHT, those who had a dilated eye exam within the past year ($p < 0.001$) were more likely to be referred. Main reasons stated by participants across the three sites for no dilated eye exam in the past 2 years for both referred and non-referred participants are shown in Table 4, with the majority stating they had no reason to go to the eye exam, not thought about the eye exam, no vision insurance, the cost of the eye exam, and other non-specific reasons.

Attendance at in-office eye exams

AL-SIGHT: A total of 396 participants (47.3%) were referred for in-office follow-up eye examinations.

MI-SIGHT: At the end of study period, 72% of participants who were high-risk referrals and 40+ years old (927 of 1271) 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 577 of these participants, of whom 481 (83%) attended follow-up. If we assume that 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 52% (481 of 927).

NYC-SIGHT: Of 468 referred participants in NYC-SIGHT, 47% ($n = 220/468$) attended the initial in-office eye exam. Adherence rates: Navigator Intervention (71.8%) versus Usual Care (28.2%).²⁹

Discussion

The SIGHT Studies recruitment approaches effectively reached underserved populations at high risk for eye diseases in geographically diverse areas.¹⁹ These community-based eye health screening settings detected the leading causes of blindness and provided a significant number of referrals for in-office eye care. For example, NYC-SIGHT recruited adults and senior residents in neighborhoods where large populations of Black and Hispanic adults live. The AL-SIGHT and MI-SIGHT Studies collaborated with FQHCs and free clinics, which provide services to those who are uninsured or insured by Medicaid. Participants with other chronic diseases, such as diabetes and hypertension, as well as existing glaucoma, also had higher referral rates and therefore benefited from the study by improving access to eye care. The AL-SIGHT clinics are located in rural areas which have limited access to ophthalmologists.^{19,20}

All three SIGHT Study locations used innovative teleophthalmology to remotely read and grade fundus images, which served as the basis for referral for in-office eye care following community-based eye health screenings. The established eye health screening and referral criteria varied across the sites but consistently detected the leading causes of eye diseases in the US. High referral rates for in-office eye care ranged from 42.8% to 66.1%, with a focus on detecting glaucoma, glaucoma suspects, cataracts, diabetic retinopathy, retinal pathology, and uncorrected refractive error. Overall, SIGHT Study results showed higher referral rates for in-office eye care for participants who were older or had a history of diabetes, hypertension, or glaucoma.

SIGHT Studies versus national prevalence data

In order to understand how the SIGHT Studies data related to national prevalence data, only enrolled participants age 40 and older were included in this comparison. Eye disease detection rates across the SIGHT Studies were compared with national crude prevalence rates for individuals 40 years and older served by Medicaid and Medicare insurance and reported in CDC's Vision and Eye Health Surveillance System (VEHSS).³⁰ The CDC's 2019 annual prevalence estimates using Medicare data were 8.0% for glaucoma and 5.27% for glaucoma suspect (combined 13.27%); Medicaid data rates were 3.9% for glaucoma and 2.13% for glaucoma suspect (combined 6.03%).³⁰ The glaucoma/glaucoma suspect findings of 18.6% in Alabama, 24% in Michigan, 26.7% in NYC detected across the three SIGHT Studies is higher than these national averages. While Medicare and Medicaid rates for glaucoma and glaucoma suspect by race and ethnicity, are higher for Black adults (18.97% Medicare/8.76% Medicaid) and Hispanic/Latino adults (13.64% Medicare/6.42% Medicaid),

compared to non-Hispanic White adults, our study findings remain higher than all of these data from 2019.³⁰ This difference is likely due to the SIGHT Studies being conducted in high-risk, underserved populations with lack of access to eye care and poor in-office eye care utilization rates.¹² Heterogeneity, or the degree of variation in the screening and referral criteria used across the three SIGHT Studies could impact the interpretation of comparative findings across different settings. We acknowledge that what worked in one setting may not be generalizable or apply in other settings.

Implementation of tele-ophthalmology

The use of telemedicine in ophthalmology has risen gradually over the last decade, with an exponential increase after the onset of the COVID-19 pandemic.^{31,32} Telehealth offers a paradigm-shifting opportunity in detecting glaucoma and retina-related eye conditions in underserved populations as a potential solution to ensure that even those with limited resources who could have remained undiagnosed, receive optimal eye care.^{33,34} Prior practice-based telehealth programs for glaucoma and retina have shown utility of screening when compared to in-office eye exams.^{35,36} Other studies have reported that telehealth for glaucoma detection reduces the amount of time spent attending in-person clinic visits and decreases travel time and costs for each patient.^{34–36} The Food and Drug Administration (FDA) has approved several devices for primary care screening of diabetic retinopathy, with implementation of these devices in many sectors.^{34,35} With growing advances in technology and the incorporation of artificial intelligence, telehealth programs for glaucoma are expected to become even more cost-effective; however, effectiveness of telehealth-based screening programs has been limited by lack of follow-up between screening events and in-office eye exams.³⁷ Teleophthalmology data from the SIGHT Studies has found a significant amount of abnormal images and with support from navigators, many of these study participants have attended in-office eye exams confirming an eye disease diagnosis.^{38,39}

Strengths

Though there was substantial variation across the sites in terms of screening tools and referral criteria leading to different referral rates and particularly different rates of uncorrected refractive error, rates of glaucoma/suspected glaucoma detected were similar across the three sites. One reason why the referral rates varied was that those with refractive error in NYC-SIGHT and AL-SIGHT were referred to optometry, while refractive error was treated as part of the screening program in MI-SIGHT. Therefore, this paper adds to the body of evidence that underserved communities benefit from the tele-ophthalmology interventions described in the SIGHT Studies. Showcasing the results side-by-side enables readers to understand that even though each study had different methodology, there were numerous findings that were shared. Placing eye disease screening in community locations with high rates of poverty was an effective approach in identifying referable eye disease across three very different geographic locations. Understanding the success of this overarching approach despite the differences between the approaches is key to informing policy.

In addition, all SIGHT Studies considered social determinants of health indicators and demographic factors to address eye health disparities by bringing eye health screenings into

the communities where people live and improved access to eye care in the community and referrals for in-office eye care for study participants who needed follow-up ocular treatment, management, and potential surgery. In AL-SIGHT a strength was that the coordinator tracked all participants referred for follow-up eye care for six months following the date of the referral. This allowed for tracking of persons who may have missed their initial appointment or had trouble getting an appointment that suited their schedule at an early date post referral.

In the MI-SIGHT Study, the ophthalmic technicians who conducted the remote telemedicine assessment also functioned as health educators and care navigators. After the remote ophthalmologist graded the data and gave follow-up recommendations, participants returned for a second visit with the ophthalmic technician. At that second visit, the ophthalmic technician dispensed the glasses from the on-line retailer and ensured a proper fit, educated the participants about the doctor's findings and recommendations, and assisted the patient in making the appropriate follow-up appointment. In addition, if a patient needed assistance with transportation, interpretation, or insurance, if the ophthalmic technician could not provide the assistance, they helped connect the participant with a social worker or a community resource to provide the assistance.

The NYC-SIGHT used a bilingual (Spanish) patient navigator to ensure that referrals were completed, including confirming and rescheduling in-office eye exam appointments. The patient navigator utilized EPIC to keep track of referrals to Columbia or Harlem Ophthalmology and to ensure patients completed and received necessary care. Those with their own doctor signed a medical release form, and only a few patients' medical records were received.

Limitations

Recruitment was limited to adults who self-selected to participate, which may not be reflective of populations at higher risk for glaucoma in other urban and rural settings and therefore may have overestimated referral rates and results in selection bias. Individuals with pre-existing ocular conditions were not excluded, which may also contribute to higher referral rates seen for participants who self-reported glaucoma compared to those not referred. On the other hand, the majority of these individuals with pre-existing glaucoma had poor access to eye care, undiagnosed ocular conditions, poor IOP lowering medication adherence, and were therefore at risk of blindness. Although slightly different screening methods and screening failure criteria definitions were used at each site, referral criteria for in-office eye care was based on *AAO Practice Pattern Guidelines*[®] and their Data and Safety Monitoring Committees. Additional factors, such as income and the presence of physical disabilities were not investigated and could influence results. Regarding referral criteria, standardized grading protocols or inter-grader reliability measures were used within each site for diagnosing "glaucoma" or "glaucoma suspect" but not across the sites, which we acknowledge does impact detection rate comparison.

Conclusion

In conclusion, the SIGHT Studies provide evidence that reaching underserved individuals at high-risk for eye disease using innovative tele-ophthalmology and eye health screenings in trusted community-based settings, detected high rates of eye disease, especially glaucoma, requiring referral to in-office eye care. These findings suggest that underserved communities with poor access to eye care can benefit from having eye care services tailored to their community's needs. Future long-term analysis of referred participant adherence to in-office eye exams will help determine the impact of the SIGHT Studies.

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Data availability statement

All deidentified participant data, study protocol, statistical plan, and informed consent will be made available by the corresponding author upon email request. The data will be made available with investigator support after approval of a proposal and a signed data access agreement is fully executed.

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Table 1.
Eye health screening measures across the SIGHT Studies.

	AL-SIGHT	MI-SIGHT	NYC-SIGHT
Visual acuity (presenting)	X	X	X
Intraocular pressure	X	X	X
Fundus photography	X	X	X
Visual field	X		
Optical coherence tomography	X	X	
Central corneal thickness (pachymetry)		X	
Autorefraction	X	X	X

Abbreviations: SIGHT, *Screening and Interventions for Glaucoma and eye Health through Telemedicine*; AL-SIGHT, University of Alabama at Birmingham SIGHT Study; MI-SIGHT, University of Michigan SIGHT Study; NYC-SIGHT, New York City SIGHT Study at Columbia University.

Table 2.

Eye conditions detected across the SIGHT Studies requiring referral.

	AL-SIGHT	MI-SIGHT	NYC-SIGHT
Total Screened, n = 4516	838	2970	708
Uncorrected refractive error, * n (%)	635 (76.8)	252 (8.5)	268 (37.9)
Vision impairment (20/50 or worse in better seeing eye), n (%)	83 (9.9)	326 (11.0)	206 (29.3)
Glaucoma/glaucoma suspect/ocular hypertension, n (%)	146 (18.6)	711 (24.0)	189 (26.7)
Diabetic retinopathy, n (%)	52 (7.1)	160 (5.5)	13 (1.8)
Macular degeneration, n (%)	19 (2.4)	64 (2.2)	8 (1.1)
Cataract, † n (%)	375 (45.9)	215 (7.7)	74 (10.5)
Other eye conditions (e.g., retina or cornea abnormalities, etc.), n (%)	121 (15.3)	471 (15.9)	40 (5.6)
Total Referred, n (%)	396 (47.3)	1271 (42.8)	468 (66.1)

Abbreviations: SIGHT, *Screening and Interventions for Glaucoma and eye Health through Telemedicine*; AL-SIGHT, University of Alabama at Birmingham SIGHT Study; MI-SIGHT, University of Michigan SIGHT Study; NYC-SIGHT, New York City SIGHT Study at Columbia University.

* AL-SIGHT used pinhole visual acuity (VA) to determine uncorrected refractive error.

MI-SIGHT used presenting VA ≤20/50 corrected to ≥20/40 in the better seeing eye.

NYC-SIGHT used uncorrected refractive error VA <20/40 in either eye.

† AL-SIGHT, ophthalmologists used a combination of optical quality of the imaging and visual acuity measurement to determine if cataracts were present, cataract severity, and referred for cataract evaluation.

MI-SIGHT, physicians graded whether cataracts were visually significant using the following guidelines: Visual acuity 20/30 or worse and/or participant difficulty with driving at night; and seeing a cataract on anterior segment photo without other pathology present on fundus exam to explain the decrement in visual acuity.

NYC-SIGHT, study optometrist determined if cataracts were present, cataract severity, and referred for cataract evaluation.

Percentages are calculated based on total screened participants, excluding missing data.

Missing data in AL-SIGHT: uncorrected refractive error (n = 11), glaucoma/suspect (n = 54), diabetic retinopathy (n = 101), macular degeneration (n = 49), cataract (n = 21) and other eye conditions (n = 49).

Missing data in MI-SIGHT: uncorrected refractive error (n = 7); vision impairment (n = 5); glaucoma/suspect (n = 5); diabetic retinopathy (n = 85) and cataract (n = 186). Missing data in NYC-SIGHT: vision impairment (n = 6).

Table 3. Participants referred and not referred for In-office eye care across the SIGHT Studies: demographics and social determinants of health indicators.

	AL-SIGHT (n = 838)			MI-SIGHT (n = 2970)			NYC-SIGHT (n = 708)		
	Referred (n = 396)	Not Referred (n = 442)	p-value	Referred (n = 1271)	Not Referred (n = 1699)	p-value	Referred (n = 468)	Not Referred (n = 240)	p-value
Age, mean (SD)	62.0 (10.9)	60.2 (10.0)	0.013**	62.5 (11.1)	58.6 (9.9)	<0.001**	70.0 (11.4)	65.7 (12.3)	<0.001**
Age, n (%)									
40–59 years	186 (45.4)	224 (54.6)	0.131	515 (35.6)	932 (64.4)	< 0.001	89 (52.4)	81 (47.6)	< 0.001
60–79 years	188 (47.8)	205 (52.2)		678 (48.1)	732 (51.9)		287 (69.0)	129 (31.0)	
≥80 years	22 (62.9)	13 (37.1)		78 (69.0)	35 (31.0)		92 (75.4)	30 (24.6)	
Race, n (%)									
Black	158 (47.9)	172 (52.1)	0.950	704 (47.6)	776 (52.4)	< 0.001	258 (70.3)	109 (29.7)	0.158
White	228 (46.9)	258 (53.1)		321 (36.1)	568 (63.9)		6 (50.0)	6 (50.0)	
Other races ⁺	10 (45.5)	12 (54.5)		163 (42.9)	217 (57.1)		19 (59.4)	13 (40.6)	
Ethnicity, n (%)									
Hispanic	3 (50.0)	3 (50.0)	1.000 [*]	147 (36.8)	253 (63.2)	0.009	185 (62.3)	112 (37.7)	0.069
Non-Hispanic	393 (47.2)	439 (52.8)		936 (43.7)	1204 (56.3)		283 (68.9)	128 (31.1)	
Sex, n (%)									
Female	253 (47.4)	281 (52.6)	0.925	774 (41.8)	1078 (58.2)	0.194	312 (67.7)	149 (32.3)	0.226
Male	143 (47.0)	161 (53.0)		484 (44.2)	610 (55.8)		156 (63.2)	91 (36.8)	
Education Level, n (%)									
High school or less than high school	260 (48.7)	274 (51.3)	0.250	551 (45.6)	658 (54.4)	0.007	296 (66.4)	150 (33.6)	0.845
Some college, college, graduate, or higher	135 (44.6)	168 (55.4)		694 (40.5)	1018 (59.5)		172 (65.6)	90 (34.4)	
Employment, n (%)									
Employed (full-time, part-time)	85 (39.4)	131 (60.6)	0.092	390 (35.9)	696 (64.1)	< 0.001	81 (57.4)	60 (42.6)	0.030
Unemployed	41 (49.4)	42 (50.6)		201 (39.1)	313 (60.9)		46 (62.2)	28 (37.8)	
Retired	123 (50.4)	121 (49.6)		439 (50.6)	428 (49.4)		290 (70.4)	122 (29.6)	
Unable to work/disabled	131 (49.1)	136 (50.9)		183 (51.0)	176 (49.0)		51 (63.0)	30 (37.0)	
Caregiver, homemaker, student, or other	16 (57.1)	12 (42.9)		45 (43.3)	59 (56.7)		0 (0.0)	0 (0.0)	

	AL-SIGHT (n = 838)			MI-SIGHT (n = 2970)			NYC-SIGHT (n = 708)		
	Referred (n = 396)	Not Referred (n = 442)	p-value	Referred (n = 1271)	Not Referred (n = 1699)	p-value	Referred (n = 468)	Not Referred (n = 240)	p-value
Marital Status, n (%)									
Single, divorced, separated, or widowed	200 (49.5)	204 (50.5)	0.208	797 (46.0)	936 (54.0)	0.001	357 (66.9)	177 (33.1)	0.459
Married or living with partner	196 (45.2)	238 (54.8)		462 (38.4)	742 (61.6)		111 (63.8)	63 (36.2)	
Health Insurance, n (%)									
Yes	323 (45.1)	393 (54.9)	0.003	957 (42.5)	1295 (57.5)	0.352	454 (67.3)	221 (32.7)	0.003
No	73 (59.8)	49 (40.2)		297 (44.5)	370 (55.5)		14 (42.4)	19 (57.6)	
Insurance Type, n (%)									
Medicare	168 (47.9)	183 (52.1)	0.765	273 (49.1)	283 (50.9)	< 0.001	287 (70.9)	118 (29.1)	0.002
Medicaid	105 (52.5)	95 (47.5)	0.089	251 (39.8)	379 (60.2)	0.091	259 (66.6)	130 (33.4)	0.766
Private or supplemental	114 (40.3)	169 (59.7)	0.004	194 (32.9)	396 (67.1)	< 0.001	133 (63.9)	75 (36.1)	0.434

Abbreviations: SIGHT, *Screening and Interventions for Glaucoma and eye Health through Telemedicine*; AL-SIGHT, University of Alabama at Birmingham SIGHT Study; MI-SIGHT, University of Michigan SIGHT Study; NYC-SIGHT, New York City SIGHT Study at Columbia University.

[†] Other Races, Asian, Pacific Islanders, American Indians, multiracial.

Table shows differences between participants referred and not referred for each indicator.

* Fisher's Exact Test,

** two-sample t-test, all other tests used Pearson Chi-Squared.

Bold *p*-value indicates statistical significance at the $p \leq 0.05$ level.

Table 4. Participants referred and not referred for In-office eye care across the SIGHT Studies: medical and ocular history.

	AL-SIGHT (n = 838)			MI-SIGHT (n = 2970)			NYC-SIGHT (n = 708)		
	Referred (n = 396)	Not Referred (n = 442)	p-value	Referred (n = 1271)	Not Referred (n = 1699)	p-value	Referred (n = 469)	Not Referred (n = 240)	p-value
Medical History, n (%)									
Diabetes	232 (50.4)	228 (49.6)	0.042	444 (53.8)	382 (46.2)	< 0.001	151 (73.3)	55 (26.7)	0.010
Hypertension	304 (47.5)	336 (52.5)	0.799	744 (47.4)	825 (52.6)	< 0.001	307 (69.1)	137 (30.9)	0.027
Cigarette Smoker	110 (52.4)	100 (47.6)	0.086	204 (39.2)	316 (60.8)	0.071	66 (64.1)	37 (35.9)	0.639
Ocular History, n (%)									
Family history of glaucoma	121 (46.2)	141 (53.8)	0.675	289 (44.6)	359 (55.4)	0.294	113 (67.3)	55 (32.7)	0.716
Glaucoma	55 (50.9)	53 (49.1)	0.413	131 (89.1)	16 (10.9)	< 0.001	71 (85.5)	12 (14.5)	< 0.001
Last Dilated Eye Exam, n (%)									
Within the past year	126 (43.4)	164 (56.6)	< 0.001	247 (56.9)	187 (43.1)	< 0.001	114 (68.3)	53 (31.7)	0.134
Within 1 to 2 years	104 (43.7)	134 (56.3)		235 (43.5)	305 (56.5)		105 (64.4)	58 (35.6)	
More than 2 years	129 (54.7)	107 (45.3)		408 (40.0)	613 (60.0)		173 (69.2)	77 (30.8)	
Can't remember	27 (52.9)	24 (47.1)		90 (40.4)	133 (59.6)		53 (64.6)	29 (35.4)	
Never had eye exam	10 (43.5)	13 (56.5)		125 (35.5)	227 (64.5)		23 (50.0)	23 (50.0)	
Main Reason for No Dilated Eye Exam in 2 Years, n (%)									
No reason to go	29 (46.0)	34 (54.0)	0.405 [*]	92 (33.1)	186 (66.9)	0.238 [*]	62 (55.9)	49 (44.1)	0.051[*]
Not thought about it	32 (58.2)	23 (41.8)		91 (43.1)	120 (56.9)		37 (62.7)	22 (37.3)	
No vision insurance	20 (45.5)	24 (54.5)		106 (38.1)	172 (61.9)		13 (52.0)	12 (48.0)	
Cost of eye exam	42 (60.0)	28 (40.0)		80 (40.0)	120 (60.0)		8 (80.0)	2 (20.0)	
Don't have an eye doctor	4 (66.7)	2 (33.3)		27 (42.2)	37 (57.8)		12 (75.0)	4 (25.0)	
Couldn't get appointment	1 (50.0)	1 (50.0)		13 (50.0)	13 (50.0)		8 (72.7)	3 (27.3)	
No transportation	7 (70.0)	3 (30.0)		9 (52.9)	8 (47.1)		4 (100.0)	0 (0.0)	
Other reasons	28 (45.9)	33 (54.1)		62 (41.9)	86 (58.1)		103 (73.0)	38 (27.0)	

Note: Abbreviations: SIGHT, *Screening and Interventions for Glaucoma and eye Health through Telemedicine*; AL-SIGHT, University of Alabama at Birmingham SIGHT Study; MI-SIGHT, University of Michigan SIGHT Study; NYC-SIGHT, New York City SIGHT Study at Columbia University.

Table shows differences between participants referred and not referred for each indicator.

^{*} Fisher's Exact Test,

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two-sample t-test, all other tests used Pearson Chi-Square.
Bold *p*-values indicate statistical significance at the $p \leq 0.05$ level.
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