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Evaluation of Diabetic Retinal Screening and Factors for Ophthalmology Referral in a Telemedicine Network

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IMPORTANCE Retinal telescreening for evaluation of diabetic retinopathy (DR) in the primary care setting may be useful in reaching rural and underserved patients.

OBJECTIVES To evaluate telemedicine retinal screenings for patients with type 1 or 2 diabetes and identify factors for ophthalmology referral in the North Carolina Diabetic Retinopathy Telemedicine Network.

DESIGN, SETTING, AND PARTICIPANTS A preimplementation and postimplementation evaluation was conducted from January 6, 2014, to November 1, 2015, at 5 primary care clinics serving rural and underserved populations in North Carolina among 1787 adult patients with type 1 or 2 diabetes who received primary care at the clinics and obtained retinal telescreening to determine the presence and severity of DR. A total of 1661 patients with complete data were included in the statistical analysis.

INTERVENTION Nonmydriatic fundus photography with remote interpretation by an expert.

MAIN OUTCOMES AND MEASURES Number of patients recruited, level of detected DR, change in rates of screening, rate of ophthalmology referral, percentage of completed referrals, and patient characteristics associated with varying levels of DR.

RESULTS Of the 1661 patients (1041 women and 620 men; mean [SD] age, 55.4 [12.7] years), 1323 patients (79.7%) had no DR, 183 patients (11.0%) had DR without a need for an ophthalmology referral, and 155 patients (9.3%) had DR with a need for an ophthalmology referral. The mean rate of screening for DR before implementation of the program was 25.6% (1512 of 5905), which increased to 40.4% (1884 of 4664) after implementation. A total of 93 referred patients (60.0%) completed an ophthalmology referral visit within the study period. Older patients (odds ratio [OR], 1.28; 95% CI, 1.11-1.48) and African American patients (OR, 1.84; 95% CI, 1.24-2.73) or other racial/ethnic minorities (OR, 2.19; 95% CI, 1.16-4.11) had greater odds of requiring an ophthalmology referral compared with white and/or younger patients. Patients with higher hemoglobin A_{1c} levels (OR, 1.19 per unit change; 95% CI, 1.13-1.25 per unit change) and longer duration of diabetes (OR, 1.76 per decade; 95% CI, 1.53-2.02 per decade) had greater odds of DR requiring an ophthalmology referral. History of stroke (OR, 1.65; 95% CI, 1.10-2.48) and kidney disease (OR, 1.59; 95% CI, 1.10-2.31) were strongly associated with DR and ophthalmology referral.

CONCLUSIONS AND RELEVANCE When implemented in the primary care setting, retinal telescreening increased the rate of evaluation for DR for patients in rural and underserved settings. This strategy may also increase access to care for minorities and patients with DR requiring treatment.

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Diabetic retinopathy (DR) is the most common microvascular complication of diabetes[1] and is the leading cause of new cases of blindness among adults 20 to 74 years of age in the United States.[2] By 2050, the prevalence of DR in patients 40 years of age or older with type 1 or 2 diabetes is projected to increase to 16.0 million (from 5.5 million in 2005), and the prevalence of vision-threatening DR is projected to increase to 3.4 million (from 1.2 million in 2005).[3]

Early detection of DR is crucial to preventing vision loss, and medical and surgical therapies have dramatically reduced the progression of DR. Timely intervention with laser and anti-vascular endothelial growth factor intravitreal therapy can reduce the risk of severe vision loss by more than 90%.[4-12] Although national and international guidelines promote annual retinal screening for patients with diabetes, rates of screening in the United States are less than 50% in the predominant health care paradigm wherein patients with diabetes are referred from primary care physicians (PCPs) to ophthalmologists for dilated eye examinations.[13-17] Socioeconomic and geographic barriers to care, delayed referrals from PCPs, and lack of patient education have been cited as reasons for low rates of screening for DR.[18-21] Among minorities, language and cultural barriers may also contribute to disparities in screening and treatment.[15,17,22] Panretinal and focal laser photocoagulation has been proven in the Early Treatment Diabetic Retinopathy Study (ETDRS),[9,10] Diabetic Retinopathy Study (DRS),[8] and Diabetic Retinopathy Vitrectomy Study (DRVS)[23] to significantly decrease vision loss. Furthermore, a recent landmark trial from the Diabetic Retinopathy Clinical Research Network has demonstrated that anti–vascular endothelial growth factor intravitreal therapy can preserve visual acuity in patients with proliferative DR.[12] The public health challenge lies first in the early identification of patients at risk of vision loss from DR on a larger scale.

Telemedicine is an emerging strategy for improving evaluation for DR through retinal imaging with remote interpretation by an expert. Introducing this technology at the point of care from the PCP could reduce many of the aforementioned barriers and improve early detection of DR. Although other countries such as the United Kingdom and France have demonstrated successful screening programs for DR using telemedicine,[24-26] large-scale data in the United States are sparse and limited primarily to the Veterans Affairs system. Although the Veterans Affairs system has demonstrated excellent rates of screening for DR,[27-30] these results are difficult to extrapolate to practice settings with a diverse mix of patients and payors.

Our goal was to evaluate telemedicine screenings for DR among patients with type 1 or 2 diabetes who live in rural and underserved parts of North Carolina. By collecting patient demographics, clinical characteristics, and socioeconomic determinants of health, we also examined factors associated with DR and the need for referral to an ophthalmologist. The other outcome measures were designed to serve as indicators for our program's success in improving delivery of eye care.

Key Points

Question How well does telemedicine retinal screening affect retinal screening for patients with type 1 or 2 diabetes in rural and underserved settings in North Carolina?

Findings This pre-post study found that the burden of advanced diabetic retinopathy requiring referral to an ophthalmologist was disproportionately high among minorities; factors associated with the need for referral included minority race/ethnicity, older age, and history of kidney disease and stroke. A total of 60% of referred patients completed an ophthalmology referral visit within the study period.

Meaning These data suggest that telemedicine increases rates of evaluation for diabetic retinopathy among patients in rural and underserved settings and may also increase access to care.

Methods

The North Carolina Diabetic Retinopathy Telemedicine Network (NCDRTN) was created as an innovative public health initiative to implement retinal telescreening to reduce rates of vision loss by providing retinal evaluations to patients with diabetes who live in rural and underserved parts of the state. This program was funded by The Duke Endowment and was a collaboration between the Department of Ophthalmology, University of North Carolina–Chapel Hill and 5 Area Health Education Center (AHEC) primary care clinics across North Carolina: Mountain AHEC in Asheville, Moses Cone Hospital Internal Medicine and Family Medicine clinics in Greensboro, East Carolina University Department of Family Medicine in Greenville, and Southern Regional AHEC in Fayetteville. The program evaluation associated with this project was approved by the University of North Carolina institutional review board. Patients provided oral informed consent at the time of recruitment.

Patient Recruitment

Inclusion criteria were patients 18 years of age or older with type 1 or 2 diabetes who received primary care in the AHEC clinics. Patients were excluded if they could not undergo retinal imaging owing to cognitive or physical impairment or if they had undergone a documented retinal examination with an eye care professional within the past 12 months. Retinal telescreening was performed in the primary care clinics, which serve large numbers of publicly insured and uninsured patients and racial/ethnic minorities. Patients were enrolled on the day of their visit. To reach the broader population, clinic electronic medical records (EMRs) were also queried to recruit patients who were due to undergo retinal screening. In addition, informational flyers and patient education brochures in English and Spanish were placed in clinic waiting areas.

Retinal Photography and Image Transfer

Existing nursing staff, clinic technicians, and/or ancillary personnel were trained as retinal camera operators. Clinical workflow models were redesigned to integrate patients undergoing imaging during their visit and to streamline referral processes. East Carolina University used an automated tabletop digital nonmydriatic fundus camera (Centervue Digital Retinography System; Centervue) to capture a single 45° macula-centered image in both eyes; all other clinics used manual tabletop cameras (VisuCam Pro NM; Carl Zeiss Meditec AG). Most patients did not require pupillary dilation.

After assessment of image quality, Digital Imaging and Communications in Medicine images and patient characteristics were securely transmitted via the Health Insurance Portability and Accountability Act–compliant RetinaVue Network (Welch Allyn).[31] Data included standard clinical diabetes metrics and social determinants of health. A single retina specialist (S.G.) at the Department of Ophthalmology, University of North Carolina–Chapel Hill remotely interpreted the images and classified severity of DR according to the International Clinical Diabetic Retinopathy and Diabetic Macular Edema disease severity scales.[32] A report containing the images, level of DR, a preliminary diagnosis, and recommendations for management was sent electronically to the originating PCP within 24 hours for incorporation into the patient's EMR. In general, patients with no DR or mild nonproliferative DR (NPDR) were scheduled for follow-up photographs within the NCDRTN in 12 months. Patients with moderate NPDR were scheduled for follow-up photographs in 6 months. Patients with diabetic macular edema, severe NPDR or proliferative DR, or ungradable images were referred to an ophthalmologist in the patient's local community who had committed to treating and managing patients in our network.

Patient Education

Prior to our network implementation, patients with diabetes in the AHEC clinics received little education regarding DR. Retinal telescreening facilitated patient education regarding diabetes and its ocular effects. To raise patient and clinician awareness of the importance of retinal screening, each clinic was provided with evidence-based educational materials from the National Eye Institute, including flipcharts, posters, online videos, and brochures in English and Spanish. Our research team also conducted site visits to deliver didactic sessions on this new eye care delivery model to attending and resident physicians as well as staff.

Data Collection

In addition to age, sex, and race/ethnicity, data were collected on standard diabetes outcomes (ie, hemoglobin A_{1c} [HbA_{1c}] level and duration of diabetes) and other associated conditions (ie, smoking, hypertension, coronary artery disease, history of stroke and/or myocardial infarction, kidney disease, and family history of glaucoma). Data on social determinants of health (ie, residential zip code, educational level, employment status, and insurance status) were also collected. This information was gathered via patient history, patient questionnaire, and/or abstraction from the patient's EMR. Rates of retinal screening were reported by each clinic both before and after implementation of the NCDRTN.

Statistical Analysis

Patient characteristics associated with DR and the need for referral to an ophthalmologist were identified. A 3-category primary outcome variable for DR and the need for referral to an ophthalmologist at the individual level was determined from retinal image results for pairs of eyes. Patients without DR in both eyes were considered to have no DR. If either eye had severe NPDR, proliferative DR, diabetic macular edema, or an ungradable image requiring referral, the patient was placed in the category of "DR with referral." Patients with mild or moderate NPDR in 1 or both eyes without diabetic macular edema were categorized as "DR without referral."

Preliminary bivariate analyses were conducted by cross-tabulating categorical variables with the primary outcome and calculating the mean (SD) values and the range for continuous variables with respect to the 3 groups (no DR, DR without referral, and DR with referral). The Pearson χ^2 test for the categorical variables was computed to test the null hypothesis of no association with the primary outcome. Analysis of variance was used to assess whether the mean values of the continuous variables varied across the 3 categories of the primary outcome.

A multivariable cumulative logits model analysis was used to identify characteristics of patients associated with DR or referral to an ophthalmologist. The first logit was the odds of DR (regardless of referral or not) relative to the odds of no DR. The second logit was the odds of referral to an ophthalmologist relative to the odds of no referral (no DR or DR without need for referral). A partial proportional odds model[33,34] was fitted to estimate odds ratios (ORs) and 95% CIs for the associations of demographic and clinical variables with the 3-category outcome. This model, which allowed the slopes for some independent variables to vary among the 2 logits, was used because the null hypothesis of proportional odds for all variables was rejected. Stepwise backward elimination with the criteria of $P < .05$ to remain in the model was used. Analysis was performed with PROC LOGISTIC in SAS, version 9.4 (SAS Institute Inc).

Results

A total of 1787 adult patients with type 1 or 2 diabetes from 5 AHEC primary care clinics were evaluated for DR within the NCDRTN from January 6, 2014, to November 1, 2015. Overall, 2006 retinal images were obtained since some patients returned for follow-up imaging during the study period. Only data from the initial visit were used in the analysis.

Before program implementation, the 5 clinics reported the retinal screening rate for their base population of patients with diabetes. The mean reported rate of screening across the 5 clinics before implementation was 25.6% (1512 of 5905), which included patients who had undergone screening by an eye care professional before enrolling in our network. After program implementation, to determine the effectiveness of the NCDRTN at reaching "active" patients with diabetes (those who had been seen by their PCP and had received at least 1 point-of-care HbA_{1c} measurement in the past 12 months) within the overall population, the 5 clinics provided the number of such patients. A total of 4664 people were reported as active patients with diabetes, and the mean rate of retinal screening after implementation was 40.4% (n = 1884).

Statistical analysis was based on 1661 patients with complete data: 1323 patients (79.7%) had no DR, 183 patients (11.0%)

Table 1. Patient Characteristics by NCDRTN Site[a]

Characteristic	Patients, No. (%) Clinic 1 (n = 435)	Clinic 2 (n = 313)	Clinic 3 (n = 327)	Clinic 4 (n = 270)	Clinic 5 (n = 316)	Total (N = 1661)
Age, mean (SD), y	54.1 (12.2)	58.7 (13.1)	54.4 (12.1)	55.9 (11.0)	54.1 (14.2)	55.4 (12.7)
Sex						
Female	277 (63.7)	187 (59.7)	214 (65.4)	170 (63.0)	193 (61.1)	1041 (62.7)
Male	158 (36.3)	126 (40.3)	113 (34.6)	100 (37.0)	123 (38.9)	620 (37.3)
Race/ethnicity						
African American	345 (79.3)	53 (16.9)	192 (58.7)	190 (70.4)	141 (44.6)	921 (55.4)
White	77 (17.7)	237 (75.7)	85 (26.0)	52 (19.3)	138 (43.7)	589 (35.5)
Hispanic	8 (1.8)	18 (5.8)	34 (10.4)	16 (5.9)	20 (6.3)	96 (5.8)
Other	5 (1.2)	5 (1.6)	16 (4.9)	12 (4.4)	17 (5.4)	55 (3.3)
Diabetes duration, mean (SD), y	9.3 (8.5)	8.3 (7.9)	8.2 (7.2)	10.3 (8.3)	9.7 (8.8)	9.2 (8.2)
HbA_{1c}, mean (SD), %	7.9 (2.5)	7.2 (1.9)	7.9 (2.5)	8.0 (2.5)	7.9 (2.4)	7.8 (2.4)
Smoking						
Yes	119 (27.4)	46 (14.7)	126 (38.5)	76 (28.1)	67 (21.2)	434 (26.1)
No	316 (72.6)	267 (85.3)	201 (61.5)	194 (71.9)	249 (78.8)	1227 (73.9)
Insurance						
Medicare	176 (40.5)	157 (50.2)	87 (26.6)	97 (35.9)	118 (37.3)	635 (38.2)
Medicaid	115 (26.4)	41 (13.1)	44 (13.5)	34 (12.6)	59 (18.7)	293 (17.6)
Private	120 (27.6)	103 (32.9)	47 (14.4)	45 (16.7)	136 (43.0)	451 (27.1)
Uninsured	24 (5.5)	12 (3.8)	149 (45.6)	94 (34.8)	3 (1.0)	282 (17.0)
Educational level						
>High school	87 (20.0)	43 (13.7)	115 (35.2)	97 (35.9)	60 (19.0)	402 (24.2)
High school degree	222 (51.0)	217 (69.3)	119 (36.4)	107 (39.6)	130 (41.1)	795 (47.9)
Some college	85 (19.5)	27 (8.6)	66 (20.2)	55 (20.4)	79 (25.0)	312 (18.8)
≥College degree	41 (9.4)	26 (8.3)	27 (8.3)	11 (4.1)	47 (14.9)	152 (9.2)
Coronary artery disease						
Yes	59 (13.6)	30 (9.6)	28 (8.6)	69 (25.6)	44 (13.9)	230 (13.8)
No	376 (86.4)	283 (90.4)	299 (91.4)	201 (74.4)	272 (86.1)	1431 (86.1)
Hypertension						
Yes	357 (82.1)	198 (63.3)	229 (70.0)	224 (83.0)	236 (74.7)	1244 (74.9)
No	78 (17.9)	115 (36.7)	98 (30.0)	46 (17.0)	80 (25.3)	417 (25.1)
Stroke						
Yes	42 (9.7)	15 (4.8)	15 (4.6)	36 (13.3)	30 (9.5)	138 (8.3)
No	393 (90.3)	298 (95.2)	312 (95.4)	234 (86.7)	286 (90.5)	1523 (91.7)
Previous MI						
Yes	44 (10.1)	27 (8.6)	19 (5.8)	34 (12.6)	35 (11.1)	159 (9.6)
No	391 (89.9)	286 (91.4)	308 (94.2)	236 (87.4)	281 (88.9)	1502 (90.4)
Kidney disease						
Yes	53 (12.2)	31 (9.9)	14 (4.3)	47 (17.4)	23 (7.3)	168 (10.1)
No	382 (87.8)	282 (90.1)	313 (95.7)	223 (82.6)	293 (92.7)	1493 (89.9)
Family history of glaucoma						
Yes	15 (3.5)	4 (1.3)	7 (2.1)	23 (8.5)	12 (3.8)	61 (3.7)
No	420 (96.6)	309 (98.7)	320 (97.9)	247 (91.5)	304 (96.2)	1600 (96.3)

Abbreviations: HbA_{1c}, hemoglobin A_{1c}; MI, myocardial infarction; NCDRTN; North Carolina Diabetic Retinopathy Telemedicine Network.

SI conversion factor: To convert HbA_{1c} to proportion of total hemoglobin, multiply by 0.01.

[a] Clinic 1: Department of Family Medicine, East Carolina University; clinic 2: Mountain Area Health Education Center; clinic 3: Moses Cone Hospital Family Medicine; clinic 4: Moses Cone Hospital Internal Medicine; and clinic 5: Southern Regional Area Health Education Center.

had DR without a need for an ophthalmology referral, and 155 patients (9.3%) had DR with a need for an ophthalmology referral. Of those who were referred, 93 patients (60.0%) completed the referral visit within the study period, which was an underestimate since several patients were still in the process of scheduling appointments at the study's end. There were 77 of 1661 ungradable images (4.6%).

Table 1 provides a detailed summary of patient characteristics for each clinic site. The mean (SD) age of patients was 55.4 (12.7) years. Women comprised a larger percentage of the study

Table 2. Characteristics of Patients: Categorical Variables

Characteristic	Patients, No./Total No. (%) No DR (n = 1323)	DR Without Referral (n = 183)	DR With Referral (n = 155)	*P* Value[a]
Sex				
Female	831/1041 (79.8)	113/1041 (10.9)	97/1041 (9.3)	.96
Male	492/620 (79.4)	70/620 (11.3)	58/620 (9.4)	
Race/ethnicity				
African American	713/921 (77.4)	107/921 (11.6)	101/921 (11.0)	.07
White	486/589 (82.5)	64/589 (10.9)	39/589 (6.6)	
Hispanic	76/96 (79.2)	9/96 (9.4)	11/96 (11.5)	
Other	48/55 (87.3)	3/55 (5.5)	4/55 (7.3)	
Smoking				
Yes	338/434 (77.9)	56/434 (12.9)	40/434 (9.2)	.34
No	985/1227 (80.3)	127/1227 (10.4)	115/1227 (9.4)	
Insurance				
Medicare	512/635 (80.6)	59/635 (9.3)	64/635 (10.1)	.19
Medicaid	229/293 (78.2)	39/293 (13.3)	25/293 (8.5)	
Private	368/451 (81.6)	44/451 (9.8)	39/451 (8.7)	
Uninsured	214/282 (75.9)	41/282 (14.5)	27/282 (9.6)	
Educational level				
<High school	309/402 (76.9)	53/402 (13.2)	40/402 (10.0)	.14
High school degree	637/795 (80.1)	76/795 (9.6)	82/795 (10.3)	
Some college	253/312 (81.1)	40/312 (12.8)	19/312 (6.1)	
≥College degree	124/152 (81.6)	14/152 (9.2)	14/152 (9.2)	
Coronary artery disease				
Yes	166/230 (72.2)	33/230 (14.3)	31/230 (13.5)	.009
No	1157/1431 (80.9)	150/1431 (10.5)	124/1431 (8.7)	
Hypertension				
Yes	981/1244 (78.9)	134/1244 (10.8)	129/1244 (10.4)	.04
No	342/417 (82.0)	49/417 (11.8)	26/417 (6.2)	
Stroke				
Yes	97/138 (70.3)	19/138 (13.8)	22/138 (15.9)	.008
No	1226/1523 (80.5)	164/1523 (10.8)	133/1523 (8.7)	
Previous MI				
Yes	117/159 (73.6)	21/159 (13.2)	21/159 (13.2)	.11
No	1206/1502 (80.3)	162/1502 (10.8)	134/1502 (8.9)	
Kidney disease				
Yes	118/168 (70.2)	25/168 (14.9)	25/168 (14.9)	.005
No	1205/1493 (80.7)	158/1493 (10.6)	130/1493 (8.7)	
Family history of glaucoma				
Yes	45/61 (73.8)	5/61 (8.2)	11/61 (18.0)	.05
No	1278/1600 (79.9)	178/1600 (11.1)	144/1600 (9.0)	

Abbreviations: DR, diabetic retinopathy; MI, myocardial infarction.

[a] Pearson χ^2 test.

Table 3. Characteristics of Continuous Variables by Main Categories

Variable	No DR (n = 1323) Mean (SD)	Range	DR Without Referral (n = 183) Mean (SD)	Range	DR With Referral (n = 155) Mean (SD)	Range	*P* Value for ANOVA
Age, y	55.3 (12.7)	18.7-93.9	53.3 (12.1)	21.2-85.2	58.0 (12.6)	27.4-87.2	.003
HbA_{1c}, %	7.5 (2.3)	4.0-17.0[a]	8.7 (2.5)	4.0-14.0	8.6 (2.6)	5.0-16.0[b]	<.001
Diabetes duration, y	8.2 (7.7)	0.01-54.0	12.8 (9.0)	0.01-51.0	13.2 (9.2)	0.01-43.0	<.001

Abbreviations: ANOVA, analysis of variance; DR, diabetic retinopathy; HbA_{1c}, hemoglobin A_{1c}.

SI conversion factor: To convert HbA_{1c} to proportion of total hemoglobin, multiply by 0.01.

[a] Two patients had an HbA_{1c} level of 17.0%, and 2 had levels of 15.0%; the remaining patients had levels of 14.0% or less.

[b] Two patients had an HbA_{1c} level of 16.0%; the remaining patients had levels of 14.0% or less.

Table 4. Odds Ratios From Partial Proportional Odds Model

Variable	Odds Ratio (95% CI)	
	DR vs No DR	Referral vs No Referral
Age (10-y units)	0.99 (0.90-1.10)	1.28 (1.11-1.48)
African American (vs white)	1.21 (0.92-1.59)	1.84 (1.24-2.73)
Hispanic or other (vs white)	1.22 (0.75-1.98)	2.19 (1.16-4.11)
HbA_{1c} level[a]	1.19 (1.13-1.25)	1.19 (1.13-1.25)
Diabetes duration (10-y units)[a]	1.76 (1.53-2.02)	1.76 (1.53-2.02)
Stroke[a]	1.65 (1.10-2.48)	1.65 (1.10-2.48)
Kidney disease[a]	1.59 (1.10-2.31)	1.59 (1.10-2.31)

Abbreviations: DR, diabetic retinopathy; HbA_{1c}, hemoglobin A_{1c}.

[a] Common odds ratio estimate and (95% CI) under the proportional odds assumption.

population than men (1041 [62.7%] vs 620 [37.3%]). The study included more African American patients (921 [55.4%]) than white (589 [35.5%]) and Hispanic patients (96 [5.8%]). The mean (SD) HbA_{1c} level was 7.8% (2.4%) (to convert to proportion of total hemoglobin, multiply by 0.01), and the mean (SD) duration of diabetes was 9.2 (8.2) years.

Coronary artery disease was associated with the primary outcome (no DR, 166 of 230 [72.2%]; DR without referral, 33 of 230 [14.3%]; and DR with referral, 31 of 230 [13.5%]; $P = .009$), as were hypertension (no DR, 981 of 1244 [78.9%]; DR without referral, 134 of 1244 [10.8%]; and DR with referral, 129 of 1244 [10.4%]; $P = .04$), stroke (no DR, 97 of 138 [70.3%]; DR without referral, 19 of 138 [13.8%]; and DR with referral, 22 of 138 [15.9%]; $P = .008$), kidney disease (no DR, 118 of 168 [70.2%]; DR without referral, 25 of 168 [14.9%]; and DR with referral, 25 of 168 [14.9%]; $P = .005$), mean (SD) age (no DR, 55.3 [12.7] years; DR without referral, 53.3 [12.1] years; and DR with referral, 58.0 [12.6] years; $P = .003$), mean (SD) HbA_{1c} level (no DR, 7.5% [2.3%]; DR without referral, 8.7% [2.5%]; and DR with referral, 8.6% [2.6%]; $P < .001$), and mean (SD) duration of diabetes (no DR, 8.2 [7.7] years; DR without referral, 12.8 [9.0] years; and DR with referral, 13.2 [9.2] years; $P < .001$) (**Table 2** and **Table 3**). All but 6 patients had an HbA_{1c} level of 14.0% or less (Table 3). The final partial proportional odds model contained age, race/ethnicity, HbA_{1c} level, duration of diabetes, stroke, and kidney disease (**Table 4**). For every 10-year increase in age, patients had 1.28 (95% CI, 1.11-1.48) times the odds of needing an ophthalmology referral compared with younger patients. Compared with white patients, African American patients had 1.84 (95% CI, 1.24-2.73) times the odds of referral, and other racial/ethnic minorities had 2.19 (95% CI, 1.16-4.11) times the odds of referral. For every 1-unit increase in A_{1c}, patients had 1.19 times the odds of having DR vs no DR (95% CI, 1.13-1.25) and needing referral vs no referral (95% CI, 1.13-1.25). For every 10 years of diabetes duration, patients had 1.76 times the odds of having DR vs no DR (95% CI, 1.53-2.02) and needing referral vs no referral (95% CI, 1.53-2.02). Patients with stroke had 1.65 times the odds of having DR vs no DR (95% CI, 1.10-2.48) and needing referral vs no referral (95% CI, 1.10-2.48). Patients with kidney disease had 1.59 times the odds of having DR vs no DR (95% CI, 1.10-2.31) and needing referral vs no referral (95% CI, 1.10-2.31).

Table 5 shows other ocular conditions incidentally diagnosed using retinal telescreening. In our study, 50 patients (3.0%) had another diagnosis in addition to DR, including age-related macular degeneration, drusen, and glaucoma.

Table 5. Frequencies of Other Diagnoses

Diagnosis	Patients, No.		
	One Eye Only	Both Eyes	Total
Age-related macular degeneration			
Grade 1 (dry)	0	4	4
Grade 2 (drusen, degenerative)	0	6	6
Grade 3 (degeneration, retinal, secondary pigmentary)	1	3	4
Grade 4 (chorioretinal scar, posterior pole)	0	1	1
Drusen (hereditary [extramacular drusen])	3	4	7
Glaucoma (optic nerve cupping)	4	11	15
Other diagnosis	8	4	12
Total	16	33	49

Discussion

By implementing a retinal telescreening program for evaluation of DR in primary care clinics across North Carolina, we suggest that telemedicine can increase the rate of evaluation of DR for a diverse group of underserved patients with type 1 or 2 diabetes. In our network population, higher HbA_{1c} levels and longer duration of diabetes were associated with advanced DR, requiring ophthalmology referral. Stroke and kidney disease were most significantly associated with DR and need for referral. A total of 1210 patients (72.8%) were publicly insured or uninsured, and 1072 patients (64.5%) were racial/ethnic minorities. It is well known that insurance status affects rates of health care use, and since the statewide prevalence of diabetes among minorities in North Carolina is estimated at 41.6%,[35] this finding suggests that our telemedicine intervention increased the reach of retinal evaluations in these traditionally underserved groups. Furthermore, racial/ethnic minority patients had higher odds of having advanced DR that required referral. After controlling for other factors, Shi et al[17] found that racial and ethnic differences are associated with low rates of diabetic eye examination, which supports the use of telemedicine in reducing barriers to access.

Our study contributes to the existing literature demonstrating the effectiveness of telemedicine in reaching underserved populations in remote, rural, or urban settings across the United States.[19-21,36-39] Owsley et al[39] reported rates and types of DR that were identified in a DR telemedicine program in 4 urban settings. Mansberger et al[37,38] conducted a relatively small study with 567 patients who were randomized to undergo either traditional screening or telemedicine screening and showed that rates of screening were significantly higher in the telemedicine group. Although we saw similar rates of DR as in the other studies, to our knowledge, our study is the first to examine demographic and clinical factors that require ophthalmology referral. These factors were minority race/ethnicity, older age, and history of kidney disease and stroke. This finding is potentially useful information for guiding the frequency of surveillance of patients who may be at increased risk for vision-threatening DR.

The implementation of ocular telemedicine programs provides an opportunity to redefine the paradigm of diabetic eye care so that PCPs can aid the ophthalmologist in the prevention, screening, and monitoring of this blinding disease. The ocular telemedicine approach increases rates of detection and surveillance for individuals with DR, thereby allowing identification of patients who can be managed and monitored by their PCPs. In our cohort, 79.7% of patients with diabetes had no DR and needed only annual photographs to be taken for surveillance, and 20.3% had some degree of DR. Telemedicine facilitated referrals to the ophthalmologist for only patients who were at risk of vision loss and required treatment or for those who had ungradable images.

Furthermore, potential socioeconomic benefits exist at every level. By requiring fewer subspecialist visits through more targeted referrals to ophthalmologists, both the patient and health care system incur fewer costs. Partnerships between ophthalmologists and PCPs that are facilitated by telemedicine create a valuable mechanism for physicians to provide patients with better access to eye care. Thus, ophthalmologists can primarily manage patients who require subspecialty expertise (ie, laser, intravitreal injections, and other surgical treatments). By identifying patients at risk of vision loss earlier in the course of disease, ocular telemedicine programs have the potential to decrease costs to the health care system and to society by reducing the economic and social burden of low vision and blindness.

There are several avenues for future work on the basis of this retinal telescreening study. As demonstrated by multiple international studies,[40-43] it would be useful to assess patient and clinician satisfaction with the convenience of retinal telescreening in primary care settings in the United States. Also, recent interest in the development of low-cost and portable retinal imaging equipment has spurred a great deal of innovation. For example, the use of handheld and smartphone-enabled cameras holds promise for the goal of reaching all patients in remote and underserved areas.[44]

Strengths and Limitations

The findings of this study should be interpreted in the context of the following limitations. Effective use of EMR systems was a challenge because each clinic used a unique EMR system to capture, measure, and track patients. Furthermore, a few sites implemented new EMR systems during the study period, and each site underwent at least 1 EMR update. Given these limitations in data reporting, it is possible that our clinics underreported the number of patients in the NCDRTN with diabetes who actually meet American Diabetes Association guidelines for DR screening and treatment.[45] In addition, examining factors associated with DR does not necessarily identify causation, and increasing rates of screening for DR does not necessarily improve rates of treatment. However, identification of patients with retinopathy is a critical first step. Also, in clinics that may already have high rates of screening for DR, telemedicine would not significantly influence rates of surveillance. However, patient satisfaction is likely to improve owing to the convenience of point-of-care screening.[46]

The major strengths of our study include a large sample size from 5 different primary care clinics across a geographically and racially diverse state. We also conducted a rigorous statistical analysis on a complete set of patient data evaluating several clinical and socioeconomic determinants of health. Rather than obtaining data only from patient questionnaires, we queried EMRs, which is a more accurate method of data collection. Having a single retinal specialist assess all retinal images provided accuracy and consistency in diagnosis. Also, the usefulness of telemedicine for long-term monitoring in preventive diabetic eye care is seen from our relatively low ophthalmology referral rate (9.3%) because we monitored patients with moderate NPDR or lesser degrees of retinopathy within the NCDRTN. Of the patients requiring ophthalmology referral, our program also had a high rate of completed visits within the study period (60.0%). Of note, this is an underestimate because several referred patients, who we did not include in this statistic, had scheduled ophthalmology appointments just outside of the study window.

Conclusions

Reducing vision loss from DR is a public health imperative. Telemedicine screening can increase rates of surveillance, reduce socioeconomic disparities, and increase access to care, ultimately preventing vision-threatening DR and improving visual outcomes and quality of life for patients with diabetes.

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