Toronto tele-retinal screening program for detection of diabetic retinopathy and macular edema

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ABSTRACT • RÉSUMÉ

Background: There are currently low rates of screening for diabetic retinopathy (DR) and sight-threatening diabetic macular edema (DME) in Ontario.

Objective: To present results of the Toronto Tele-Retinal screening program for patients with diabetes mellitus and to evaluate the benefit of optical coherence tomography (OCT) in combination with monoscopic colour fundus photographs for detection of DME.

Methods: All electronic medical records for adults with type I and II diabetes mellitus screened through the Toronto Tele-Retinal screening program between September 2013 to August 2017 across 7 sc~reening sites in urban and rural settings were reviewed. Monoscopic colour fundus photographs were graded for presence or absence of DR and DME alone and in combination with OCT scans.

Results: A total of 775 patient screens, consisting of 566 first-time screens and 209 re-screens were completed over the 48-month study period. Approximately 37% of all patients with a mean disease duration of 7 years had never had an eye examination. Across the sample, 27% of patients had DR, with majority graded to have mild DR, whereas DME was detected in 5% of patients in at least 1 eye. Of all DME detected in the Toronto Tele-Retinal screening program, 38% required the use of adjunct OCT. Other pathologies, including age-related macular degeneration (19%) and glaucomatous or optic nerve findings (8%), were also identified.

Conclusion: Tele-retinal screening programs may circumvent low rates of DR screening for patients with diabetes mellitus and increase the rate of detection of DME with monoscopic colour fundus photographs and adjunct OCT.

Contexte: À l'heure actuelle, le taux de dépistage de la rétinopathie diabétique (RD) et de l'œdème maculaire diabétique (OMD) menaçant la vue est faible en Ontario.

Objectif: Présenter les résultats du programme de télédépistage de la rétinopathie de Toronto (TTRSP, pour *Toronto Tele-Retinal screening program*) à l'intention des patients atteints de diabète, et évaluer les avantages de la tomographie par cohérence optique (OCT, pour *optical coherence tomography*) conjointement aux photographies monoscopiques en couleurs du fond d'œil dans le dépistage de l'OMD.

Méthodes: On a examiné tous les dossiers médicaux électroniques d'adultes présentant un diabète de type 1 et 2 qui ont fait l'objet d'un dépistage par l'intermédiaire du TTRSP entre septembre 2013 et août 2017 dans 7 centres de dépistage urbains et ruraux. Les photographies monoscopiques en couleurs du fond d'œil ont été classées en fonction de la présence ou de l'absence de RD et d'OMD, seules et en association aux tomographies.

Résultats: Au total, 775 dépistages, soit 566 nouveaux dépistages et 209 dépistages répétés, ont été réalisés pendant les 48 mois de l'étude. Environ 37 % des patients dont l'affection remontait en moyenne à 7 ans n'avaient jamais subi d'examen de la vue. Au sein de l'échantillonnage, 27 % des patients présentaient une RD (légère dans la majorité des cas), tandis qu'on a diagnostiqué un OMD dans au moins 1 œil chez 5 % des sujets. Parmi les cas d'OMD dépistés dans le cadre du TTRSP, on a dû recourir à l'OCT chez 38 % des sujets. D'autres affections, notamment la dégénérescence maculaire liée à l'âge (19 %) et des lésions glaucomateuses ou touchant le nerf optique (8 %), ont également été découvertes.

Conclusions: Les programmes de télédépistage de la rétinopathie peuvent être une solution aux faibles taux de détection de la RD chez les diabétiques, et accroître le taux de dépistage d'OMD grâce aux photographies monoscopiques en couleurs du fond d'œil associées à l'OCT.

Diabetic retinopathy (DR) is the most common microvascular complication of diabetes mellitus[1] and one of the leading causes of vision loss in Canada.[2] The increasing prevalence of diabetes mellitus is observed in both urban and rural settings in Canada and is estimated to reach 3.7 million by 2018.[3] Early detection of DR in the initial stages of the disease trajectory dramatically slows progression from mild and moderate nonproliferative DR to severe nonproliferative DR and proliferative DR and reduces risk of developing sight-threatening diabetic macular edema (DME).[4,5] Timely interventions such as antivascular endothelial growth factor intravitreal therapy and panretinal and focal laser photocoagulation significantly decrease vision loss.[6–10] The Canadian Ophthalmological Society recommends initiating screening for adults with type II diabetes mellitus at the time of diagnosis and for type I diabetes mellitus, 5 years after the diagnosis.[11] Despite these recommendations, studies have revealed that a substantial proportion of individuals with diabetes in Canada do not receive the recommended eye care.[12,13] The 2005 Community Health Survey of Canadians suggested that more than 30% of individuals with diabetes have never had an eye examination, and 52% have not had an examination within the last year.[14]

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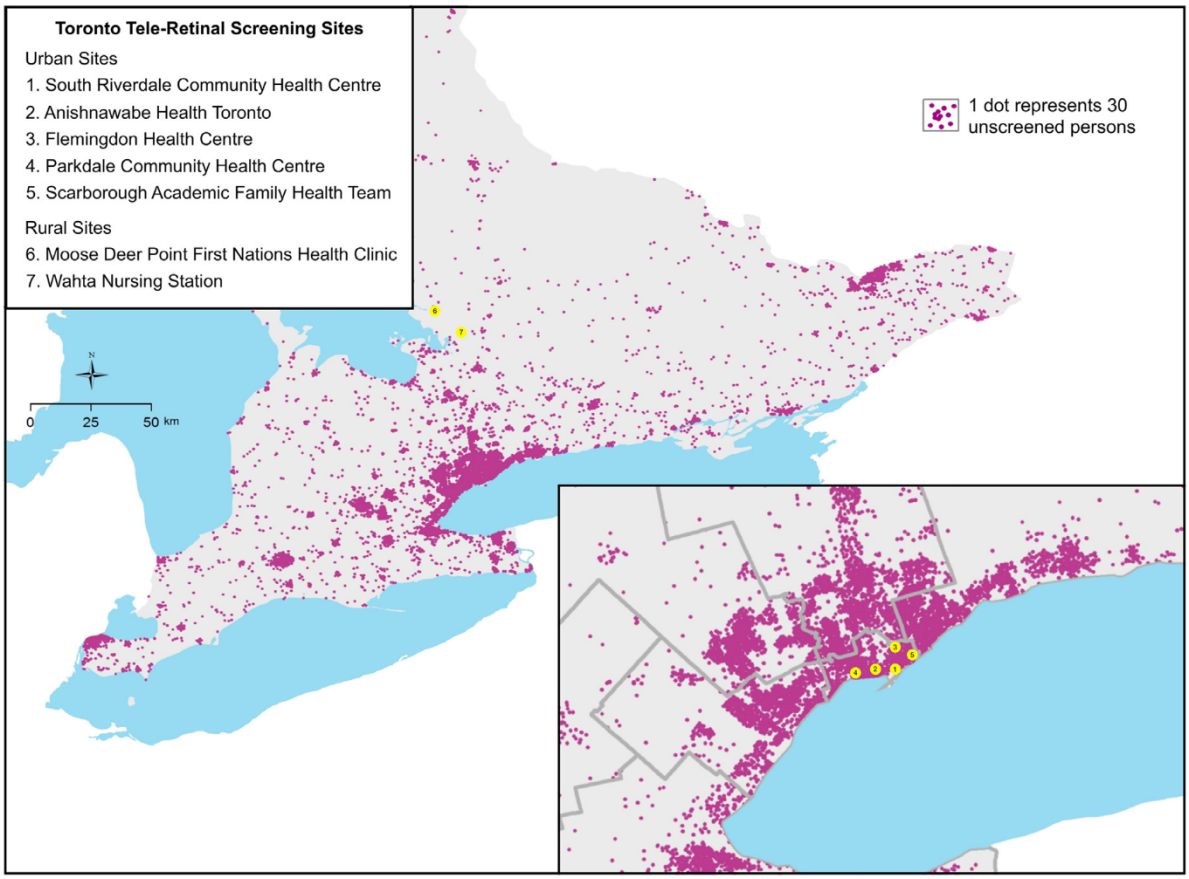

Fig. 1—Rate of individuals with diabetes mellitus living in Ontario who have not had an eye examination to screen for diabetic retinopathy between years 2011 and 2013. Approximately 35.4% (405 967 of 1 145 645) of individuals with diabetes mellitus have not been screened for diabetic retinopathy or diabetic macular edema according to the Clinical Evaluative Sciences (ICES) Improving Screening for Diabetic Retinopathy in Ontario project. The numbered yellow symbols depict the locations of the 7 screening sites included in the Toronto Tele-Retinal screening program aimed at increasing rates of diabetic retinopathy screening for patients with diabetes mellitus in urban (1–5) and rural (6, 7) settings of Ontario.

Within Ontario, the burden of diabetes affects one and a quarter million people in both urban and rural settings, more than 400 000 of whom have not been screened for DR over a 2-year period (Fig. 1).[15] The low rates of compliance with screening have been attributed to limited accessibility to eye care professionals, socioeconomic and geographic challenges, restricted mobility associated with poor health, and lack of awareness.[16–19] The asymptomatic latent period of DR that precedes vision loss creates further challenges in DR screening.[20,21]

Recent technological advances have resulted in a radical transformation of health care delivery in increasingly broader and feasible contexts through telemedicine. The application of telemedicine to clinical ophthalmology, also known as tele-ophthalmology, is well recognized by the Canadian ophthalmological landscape as a sensitive and cost-effective means of identifying those at greatest need for further ophthalmic assessment.[11] Several initiatives in the United States and across the globe have also described models of tele-ophthalmology for screening patients with diabetes.[22–26] Tele-retinal screening refers to tele-ophthalmology with a focus on sight-threatening retinal diseases. With the anticipated increase in demand for DR screening in Canada, tele-retinal screening programs may circumvent difficulties in accessibility by bringing DR screening services into urban and rural settings. The novel use of adjunct optical coherence tomography (OCT), in combination with monoscopic colour fundus photographs, shows promise for incorporation into practice guidelines in the near future.[27,28] The Toronto Tele-Retinal screening program was developed to optimize DR screening in the primary care setting. Herein, we present the characteristics of patients with type I and II diabetes mellitus enrolled in the Toronto Tele-Retinal screening program, evaluate the added benefit of OCT technology in combination with monoscopic colour fundus photographs for detection of DME, and discuss the demand for tele-retinal screening programs in urban and rural settings.

Methods

This was a consecutive retrospective case series and comparative analysis of imaging technology. A review of electronic medical records of all patients enrolled in the Toronto Tele-Retinal screening program between September 2013 to

August 2017 was conducted across 7 screening sites in urban (South Riverdale Community Health Centre, Anishnawabe Health Toronto, Flemingdon Health Centre, Parkdale Community Health Centre, and Scarborough Academic Family Health Team) and rural (Moose Deer Point First Nations Health Clinic and Wahta Nursing Station) settings. The communities invited to participate in the Toronto Tele-Retinal screening program either had a population focus and/or were located in areas with low-income status. The patient population eligible for the program consisted of adults (18 years and older) with a diagnosis of type I or type II diabetes mellitus who had not had an eye examination within the past year and were not currently under the care of an eye care provider involved in monitoring their eye health. The screening program enrolled individuals with provincially qualified health insurance (Ontario Health Insurance Plan [OHIP], which pays for medically necessary health care services for Ontario residents), as well as those who had no health insurance (at no cost to the patient). Patient population was identified by referrals from multidisciplinary health care providers (family physicians, nurse practitioners, and diabetes education program personnel). The Toronto Tele-Retinal screening protocol for classification of DR and DME was adapted from several existing established guidelines (Appendix A, available online).[11,29–37] Follow-up recommendations for screenings were based on Canadian Ophthalmological Society guidelines of annual examinations for mild nonproliferative DR, and more frequent examinations at 3–6-month intervals for other types of DR based on disease severity level.[11,38,39] Re-screening was offered annually to patients with no evidence of DR.[40–42] Results of a short patient survey distributed to a random sample of program participants to evaluate their experience with the program and identify barriers to accessibility of ophthalmic assessment were also retrospectively reviewed. A detailed review of the Toronto Tele-Retinal screening program design and screening protocol is included in Appendix B (available online). Approval for the conduct of this study was obtained from Institutional Review Board for Human Subjects Research at the University Health Network, University of Toronto, Research Ethics Board, and the study protocol adhered to the tenets of the Declaration of Helsinki.

Adjunct OCT for Detection of DME

A senior retina specialist (M.H.B.) and a second grader (T.F.) graded all 2-field monoscopic colour fundus photographs (centred on the macula and the optic nerve) for presence or absence of DME and other retinal pathologies for each eye screened in the program while masked to OCT scans (5-line raster line spectral-domain). Presence or absence of DME and other retinal pathologies was documented. The presence or absence of DME and other retinal pathologies was re-evaluated for all images with direct side-by-side OCT scans. The final adjudicated prevalence of DME was compared between the monoscopic colour fundus photographs alone in combination with OCT scans. Quality of monoscopic colour fundus photographs was graded on a 3-point scale (fair, poor, or unavailable) by the 2 graders. All patient demographic information obtained from the standardized referral form as well as screening data such as habitual visual acuity and intraocular pressure were available to graders during the grading process.

Statistical Analysis

Descriptive statistics were used to report patient demographics and main outcomes. The association between the outcome variables were assessed by t test for comparing mean values, and Fisher exact test for proportional differences. All statistical analyses were performed with commercially available software (SPSS software version 14.0; SPSS Inc). The α-level (type I error) was set at 0.05.

Results

A total of 775 patient screens, consisting of 566 first-time screens and 209 re-screens, were completed over the 48-month study period (Table 1). The percentage of patients not

Table 1—Characteristics of patients enrolled in the screening program

Variable	Number (%) or mean ± SD
Total patients screened	566
Sex	
Female	296 (52.3)
Male	270 (47.7)
Age, y	56.2 ± 12.1
Age group, y	
20–39	41 (7.2)
40–64	403 (71.2)
≥65	122 (21.6)
Insurance status	
Provincial health insured (OHIP)*	524 (92.6)
No provincial health insurance	42 (7.4)
Diabetes type	
Type I	10 (1.8)
Type II	556 (98.2)
Insulin use†	143 (25.3)
Age at diabetes diagnosis, y‡	48.5 ± 12.2
Duration of diabetes, y‡	7.3 ± 7.2
HbA_{1c} level known§	535
Reported HbA_{1c} level§	7.9 ± 1.9
Known pre-existing comorbidities‖	
Hypertension	202 (35.7)
Cardiovascular disease	178 (31.4)
Kidney disease	47 (8.3)
Neuropathy	41 (7.2)
Smoking status¶	
Current	112 (19.8)
Former	31 (5.5)
Never	364 (64.3)
Unknown	59 (10)
Last dilated eye examination	
≤2 years	232 (41)
>2 to ≤5 years	99 (17.5)
>5	25 (4.4)
Never	210 (37.1)
Known past ocular disease**	73 (12.9)

*Ontario Health Insurance Plan (OHIP).
†Insulin use unknown for 10 patients.
‡This information was reported as unknown in 34 patients.
§Abbreviation for glycated haemoglobin.
‖All health-related measures are according to information reported by referring health care professional in referral form.
¶Any form of tobacco use.
**Includes all previous ocular diagnoses, treatments, and/or surgeries reported in referral form.

covered by OHIP was 7.4% (42 of 566) and the rate of eye examination within the past 2 years was 41% (232 of 566). Of the patient re-screens, there were 158 second, 43 third, and 8 fourth annual visits to the Toronto Tele-Retinal screening program. The largest number of patient screens was completed at South Riverdale Health Centre (38.6%, 299 of 775), Flemingdon Health Centre (22.6%, 175 of 775), and Parkdale Community Health Centre (20%, 155), followed by Anishnawabe Health Toronto, Moose Deer Point First Nations Health Clinic, Wahta Nursing Station combined (12.4%, 96 of 775), and Scarborough Academic Family Health Team (6.5%, 50 of 775). Over the study period, 134 referrals were received between 2013 and 2014, and 471 referrals between 2015 and 2016, and 170 during the first 8 months in 2017. Referrals were sent from family physicians (83.2%, 645 of 775), nurse practitioners (15.6%, 121 of 775), and diabetes education program personnel (1.2%, 9 of 775).

A total of 1550 eyes were screened for DR and DME (Table 2). Across the entire sample, 26.6% (206 of 775) of the participants had DR. Within the sample of participants with DR, 33.5% (69 of 206) had notable disease in 1 eye and 66.5% (137 of 206) had DR in both eyes. The overall rate of DME was 4.6% (36 of 775), and within the sample of patients with DME, disease was monocular in 57.1% (20 of 35) and binocular in 42.9% (15 of 35) of cases. The use of OCT technology was deemed to be necessary for determining presence or absence of DME in 13.5% of eyes (210 of 1550; Table 3). Compared with the 3.2% rate of DME detected on OCT (50 of 1550), monoscopic colour fundus photographs significantly overestimated the prevalence of DME to be 12.3% (191 of 1550) for all eyes ($p < 0.001$). Only 62% (31 of 50) of all DME detected in the screening program was identified on monoscopic colour fundus photographs alone, and thus 38% (19 of 50) of all DME were missed without the use of OCT. Of the eyes without suspected DME, 32.6% (437 of 1340) required the use of OCT for determining presence or absence of other pathologies noted on monoscopic colour fundus photographs such as suspected neovascular age-related macular degeneration (Fig. 2). With the use of OCT, presence of suspected pathology was confirmed in 4.6% (62 of 1340), and ruled out in 25.5% (342 of 1340) of eyes. Monoscopic fundus photographs alone failed to detect pathologies identified with OCT scans in 2.5% (33 of 1340) of eyes.

Arrangements for timely ophthalmologic appointments were made for 46.1% (357 of 775) of screenings completed based on screening findings, whereas the remaining 51.1% (396 of 775) of screenings were advised to return to Toronto Tele-Retinal screening or visit an eye care professional within 12 months. Of all cases advised to return for annual re-screening within 12 months, 52.8% (209 of 396) returned to the Toronto Tele-Retinal screening program for re-screening as suggested. Within the group of patients returning for re-screening, 63.6% (133 of 209) returned within 2 months of the suggested time interval. Unavailable or poor quality monoscopic colour fundus photographs (poor photographic location/focus/constricted pupils/contrast or media opacity) limited accurate screening in 2.8% (22 of 775) of cases, and thus these patients were advised to return for re-screening within 1–2 months.

Retrospective review of program satisfaction survey results of a random selection of 330 patients across all 7 screening sites suggested that 91.6% of respondents rated their experience with the program as "excellent," 8.4% rated it as "good,"

Table 2—Summary of ocular characteristics and screening results

Variable	Number (%) or mean ± SD
Total screens completed	775
First visit screens	566
Re-screens	209
Visual acuity with habitual correction	
≥20/30	467 (60.3)
<20/30 to ≥20/50	247 (31.9)
<20/50 to ≥20/100	51 (6.6)
<20/100	10 (1.3)
Monocular patient	9 (1.2)
Visual acuity, logMAR; Snellen	0.3 ± 0.4; 20/40
Intraocular pressure	
≥21 mm Hg*	162 (20.9)
≥30 mm Hg*	10 (1.3)
Intraocular pressure, mm Hg	16.73 ± 3.9
Diabetic retinopathy severity	
Absent	548 (70.7)
Nonproliferative diabetic retinopathy	
Mild	117 (15.1)
Moderate	64 (8.3)
Severe	19 (2.5)
Proliferative diabetic retinopathy	
High risk	2 (0.3)
Quiescent	4 (0.5)
Ungradable	20 (2.6)
Diabetic macular edema	
Present	35 (4.5)
Ungradable	3 (0.5)
Other ocular findings	
Age-related macular degeneration	148 (19.1)
Early/intermediate	142 (18.2)
Advanced	6 (0.8)
Glaucomatous or optic nerve findings	59 (7.6)
Hypertensive retinopathy	15 (1.9)
Choroidal nevi/retinal scar	12 (1.5)
Epiretinal membrane	19 (2.5)
Vitreous pathologic findings†	22 (2.8)
Miscellaneous‡	7 (0.9)

*Intraocular pressure measurements were declined by 8 patients.
†Includes posterior vitreous detachment, asteroid hyalosis, vitreous opacity, and vitreomacular traction.
‡Noted in 5 or fewer eyes (macular hole, vein or artery occlusion, lattice and peripheral degenerations, and polylpoidal choroidal vasculopathy).

Table 3—Monoscopic colour fundus photograph (MCFP) alone and in combination with optical coherence tomography (OCT) for detection of diabetic macular edema (DME)

Variable	Number (%)
Eyes screened	1550
Prevalence of DME	
MCFP alone	191 (12.3)
MCFP and OCT	50 (3.2)
p	<0.001
OCT deemed necessary for making diagnosis	210 (13.5)
DME noted on MCFP but not OCT	160 (76.2)
DME detected on MCFP and OCT	31 (14.8)
DME detected on OCT but not MCFP	19 (9)
Fair MCFP image quality*	11 (57.9)
Poor quality/unavailable MCFP image*	8 (42.1)

*Image quality based on graders' quantification of clarity of image on a 3-point scale (fair, poor, no image/unavailable).

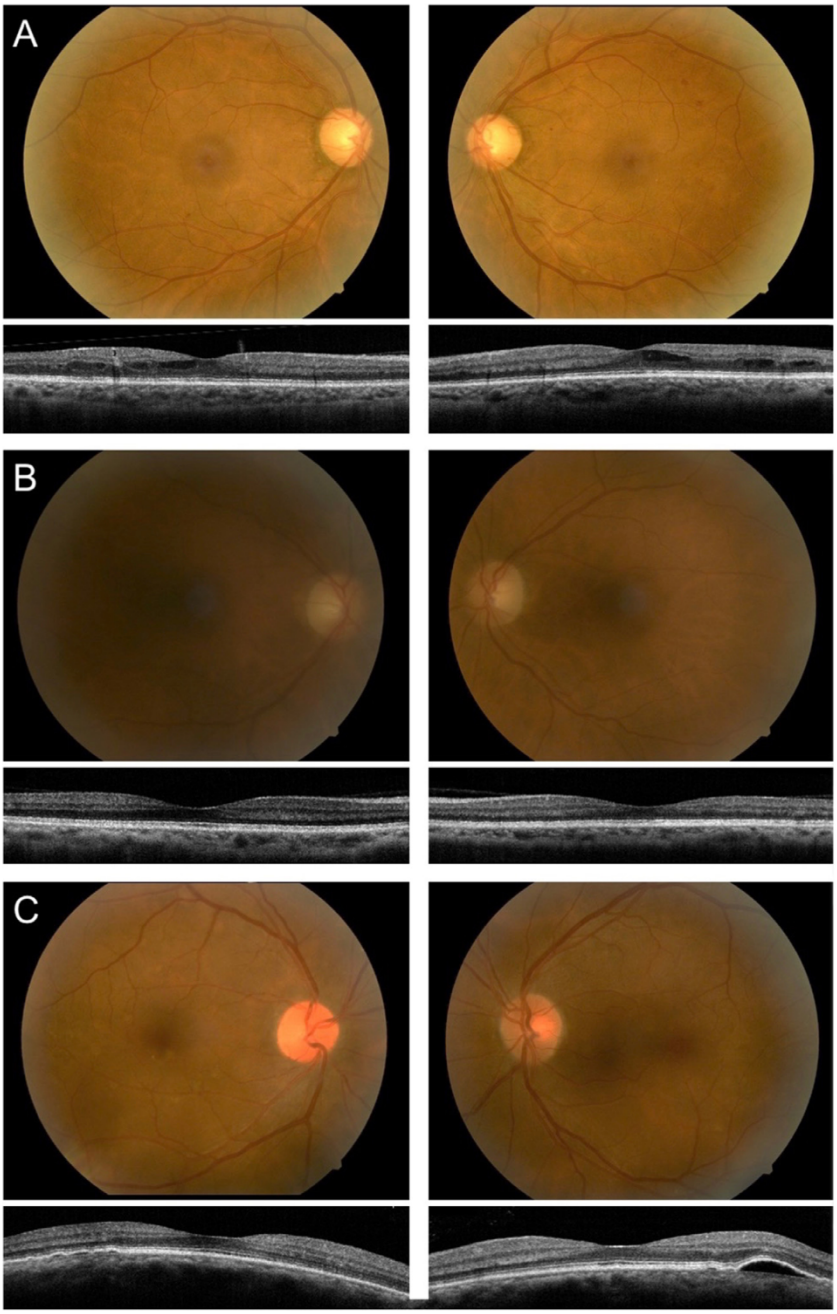

Fig. 2—Selected monoscopic colour fundus photographs and associated optical coherence tomography (OCT) scans of right and left eyes of patients screened for presence or absence of diabetic retinopathy (DR), diabetic macular edema (DME), and other retinal pathologies. (A) **A 68-year-old male with mild DR on monoscopic colour fundus photographs, and DME only detectable on OCT scan. This patient was promptly referred to a retina specialist.** (B) **A 60-year-old female with hazy view of the right eye on monoscopic colour fundus photograph, confirmed to have no DME with the help of adjunct OCT scans. This patient was advised to return for re-screening with Toronto Tele-Retinal screening program or an eye care professional within 1–2 months.** (C) **A 53-year-old male with incidental retinal pathology findings on monoscopic colour fundus photographs that may represent polypoidal choroidal vasculopathy based on OCT scans. This patient was referred for follow-up with an ophthalmologist within 3–6 months.**

and none reported their experience as "poor." With regard to reasons for not having been screened previously, the majority of respondents (71.7%) reported lack of awareness about DR, whereas others reported concerns with regard to the cost (23.7%) and travel (3.5%) associated with DR screening as one of the barriers to seeking eye care.

Discussion

This study presents the results of the Toronto Tele-Retinal screening program, for detection and determining severity of DR and DME in patients with type I and type II diabetes mellitus in urban and rural settings. This collaborative initiative with family physicians, nurse practitioners, and diabetes

education program personnel enabled enrolment of 566 patients and a total of 775 screens over a 48-month period. The Institute of Clinical Evaluative Sciences (ICES) data suggest that approximately 35.4% of individuals with diabetes living in Ontario have not had a DR screening eye examination over a 2-year period. Comparatively, our results demonstrate that 37.1% of patients enrolled in the Toronto Tele-Retinal screening program had never had an eye examination. Amongst the screened sample, the prevalence of DR was 26.6%. Aligned with the percentages reported by screening programs in primary care settings in the United States and Canada,[43–45] in our program patients were most likely to have mild DR (15.1%) than moderate (8.3%) and severe (2.5%). However, vision-threatening DR was also noted in the form of severe nonproliferative DR (2.5%), high-risk proliferative DR (0.3%), and DME (4.5%), comprising 7.4% of the total cohort. Other Canadian tele-ophthalmology screening program in the provinces of Quebec,
British Columbia, Alberta, Manitoba, and Saskatchewan have suggested a 22.5% prevalence of DR, with 1.8% of patients requiring urgent referral for proliferative DR or DME.[46] Another published study of tele-ophthalmology screening in Alberta identified DR in 27.2% of patients and particularly proliferative DR in 2.3%.[44]

The use of OCT technology in clinical settings has gained popularity over the past few years and offers increased sensitivity and precision for detection of ocular pathologies when combined with monoscopic colour fundus photographs.[27,47–49] Previous studies have shown that OCT technology may be beneficial in reducing overestimation of prevalence of DME noted on monoscopic colour fundus photographs by 42.1%.[50] Our comparative analysis demonstrated that the prevalence of DME was overestimated at 12.3% with monoscopic colour fundus photographs alone compared to 3.2% rate of DME using monoscopic colour fundus photographs with adjunct OCT. More importantly, 38% of all DME identified in the Toronto Tele-Retinal screening program were not detected by monoscopic colour fundus photographs alone, which may be partly attributed to the low quality of images (e.g., constricted pupils, media opacity, and poor imaging technique).

Detection and appropriate management of other pathologies such as age-related macular degeneration and glaucomatous or optic nerve findings have been suggested to be a critical part of tele-ophthalmology screening programs.[51,52] Our screening program had a 19.1% rate of pathological finding of age-related macular degeneration similar to previous reports from screening programs, which have suggested a rate of 23% related to cataract and age-related macular degeneration.[13] Adjunct OCT was also essential for detection of 2.5% of retinal pathologies not detected on monoscopic colour fundus photographs alone. Additionally, of all screenings completed, 7.9% of patients did not meet the Ontario Ministry of Transportation vision standards[53] of 20/50 or better, measured on Snellen charts with habitual correction in at least 1 eye. Duration of diabetes was monitored as an important consideration of our screening program due to its strong link to the development of DR[54] and was on average reported to be 7.3 years. Given that kidney disease and neuropathy, suggested to be most associated with DR,[55] were noted in only 8.3% and 7.2% of the patients enrolled in the program, respectively, detection of DR may serve as an early sign of disease severity for patients requiring multidisciplinary care. Through early identification of patients at risk of vision loss, the tele-retinal screening programs have the potential to decrease burden of chronic complications of diabetes in this patient cohort.

The Canadian Ophthalmological Society states that there is a high-level of evidence for effectiveness of tele-ophthalmology programs in enhancing access and compliance with monitoring in culturally and economically isolated populations of individuals with diabetes.[11] Tele-ophthalmology screening programs have also demonstrated efficacy in increasing accessibility to patients in both urban and rural settings.[44,56] As illustrated by Kanjee and colleagues[57] tele-ophthalmology screening is a cost-effective means of detecting and monitoring ocular disease and has an average savings per examination of $1007 in Canadian dollars. Other international tele-ophthalmology programs have demonstrated the cost-effectiveness and reliability of tele-ophthalmology screening.[26,58,59] The use of monoscopic colour fundus photography in combination with OCT may have comparable detection of DR and DME as stereoscopic colour fundus photography, which has been suggested to be the gold standard for detection and classification of DR through tele-ophthalmology in Canada.[60,61] Despite the associated initial costs of the OCT device installation, the simplicity of image acquisition and interpretation may be another benefit of monoscopic colour fundus photography in combination with OCT when compared to stereoscopic colour fundus photography imaging technology in a tele-ophthalmology screening program.[62,63] With the development of automated retinal image analysis systems (ARIAS)[64–66] and deep learning systems (DLS),[67,68] which allow for detection of DR and other eye diseases without the need for a human grader, there is a promising future for even more cost-effective means of DR screening in various health care settings. Current studies have illustrated the potential applicability of monoscopic colour fundus photography and OCT in automated screening,[69–72] and provide support for these systems' role in further enhancing accessibility, efficiency, and sensitivity of tele-ophthalmology screening programs.[73,74]

In our patient survey, 23.7% of the patient sample reported concerns with regards to cost of DR screening as a barrier to seeking eye examinations. Despite wide accessibility to a provincial health plan amongst the majority of our patients, 7.4% did not have any form of health insurance plan and thus that may have served as a barrier to accessing appropriate eye examinations. Furthermore, 78.4% of patients enrolled in the program were between the age of 20 and 65 years, who may have been misinformed about their Ontario Health Insurance Plan coverage for routine eye examinations once every 12 months plus additional follow-up assessments.[75] Patient education and awareness about

complications of diabetes, including DR and DME, and connecting patients with appropriate eye examination services are essential aspects of the Toronto Tele-Retinal screening program. Our patient survey results demonstrating a lack of awareness about DR in 71.1% and a high satisfaction rate of 91.6% further attest to the usefulness of the services provided to those enrolled in the screening program. Although many of our patients returned to the screening program for re-screening, adherence with assessments following screening may be complicated by barriers such as travel and accessibility, and thus many of the advantages of the screening program may be undermined.[76] Collaboration between the screening program and primary care providers, as presented in our program, will ensure longitudinal follow-up and better adherence to suggested follow-up assessments. Since the conduction of this study, our program has expanded to 5 additional screening sites: Lawrence Heights Community Centre, Bathurst-Finch Community Hub, Jane-Trethewey Community Hub, Keele-Rogers Community Hub, and LAMP Community Health Centre. These initiatives aim to increase accessibility of the Toronto Tele-Retinal screening program to a larger and more diverse patient population.

Limitations

The findings of this study should be interpreted with consideration of the following limitations. Although our study included a total of 775 screens and 1550 eyes, only 207 screens had any level of DR. This small sample size of DR limits the overall generalizability of our findings. Furthermore, with only 2 rural screening sites enrolled in the program, the applicability of the results may be limited and thus our findings should be interpreted with caution. Given that our screening program was conducted in several sites within Ontario, our findings may be unique to our province but will nonetheless add to the existing literature on tele-ophthalmology within other provinces in Canada. The authors acknowledge that accessibility to follow-up examinations beyond the Toronto Tele-Retinal screening program may be limited by factors such as travel distance, cost, and lack of health insurance. Efforts were made to contact patients after the completion of the screening program to ensure that follow-up was arranged with the appropriate level of eye care provider. To protect patient privacy, we did not have access to follow-up eye examination findings and clinical care information for patients who were placed with an eye care provider outside of the screening program.

Conclusions

There are currently low rates of screening for DR and sight-threatening DME in Ontario. The Toronto Tele-Retinal screening program aimed to increase accessibility to screening amongst adults with diabetes mellitus in urban and rural settings. The program completed a total of 775 screens (1550 eyes) between September 2013 to August 2017. Approximately 37.1% of all patients with a mean diabetes duration of 7.3 years screened in our program had never had an eye examination most commonly due to lack of awareness about DR. Amongst 775 screenings completed, the prevalence of DR was 26.6%, with sight-threatening DR making up 7.4% of the overall sample. Our findings suggest that adjunct OCT increases rate of detection for DME and other retinal pathologies otherwise not detected on monoscopic colour fundus photographs alone. Indeed, 38% of all DME identified in the Toronto Tele-Retinal screening program required the use of adjunct OCT. The screening program also identified other pathologies, including age-related macular degeneration (19.1%), glaucomatous or optic nerve findings (7.6%), and hypertensive retinopathy (1.9%). Arrangements for timely ophthalmologic appointments were made for 46.1% of all screenings completed. Overall, tele-retinal screening programs may increase accessibility to eye care services and reduce risk of undiagnosed sight-threatening eye disease in both urban and rural settings.

Supplementary materials

Supplementary material associated with this article can be found in the online version, at doi:10.1016/j.jcjo.2018.07.004.

References

1. Deshpande AD, Harris-hayes M, Schootman M. Epidemiology of diabetes and diabetes-related complications pathophysiology of diabetes. *Phys Ther*. 2008: 881254–64.
2. Cruess AF, Gordon KD, Bellan L, Mitchell S, Pezzullo ML. The cost of vision loss in Canada. 2. Results. *Can J Ophthalmol*. 2011;46:315–8.
3. Public Health Agency of Canada. *Diabetes in Canada: Facts and Figures from a Public Health Perspective*; 2011.
4. Lee R, Wong TY, Sabanayagam C. Epidemiology of diabetic retinopathy, diabetic macular edema and related vision loss. *Eye Vis (London)*. 2015;2:17.
5. Solomon SD, Chew E, Duh EJ, et al. Diabetic retinopathy: a position statement by the American Diabetes Association. *Diabetes Care*. 2017;40:412–8.
6. The Diabetic Retinopathy Study Research Group. Photocoagulation treatment of proliferative diabetic retinopathy: clinical application of Diabetic Retinopathy Study (DRS) findings, DRS Report Number 8. *Ophthalmology*. 1981;88:583–600.
7. Writing Committee for the Diabetic Retinopathy Clinical Research Network. Panretinal photocoagulation vs intravitreous ranibizumab for proliferative diabetic retinopathy: a randomized clinical trial. *JAMA*. 2016;33647:2137–46.
8. Early Treatment Diabetic Retinopathy Study Research Group. Early photocoagulation for diabetic retinopathy: ETDRS Report Number 9. *Ophthalmology*. 1991;98:766–85.
9. Wells JA, Glassman AR, Ayala AR, et al. A flibercept, bevacizumab, or ranibizumab for diabetic macular edema two-year results from a comparative effectiveness randomized clinical trial. *Ophthalmology*. 2016;123:1351–9.
10. The Diabetic Retinopathy Clinical Research Network. Aflibercept, bevacizumab, or ranibizumab for diabetic macular edema. *N Eng J Med*. 2015;372:1193–203.
11. Hooper P, Boucher MC, Cruess A, et al. Excerpt from the Canadian Ophthalmological Society evidence-based clinical practice guidelines for the management of diabetic retinopathy. *Can J Ophthalmol*. 2017;52:S45–74.
12. Sloan FA, Brown DS, Carlisle ES, Picone GA, Lee PP. Monitoring visual status: why patients do or do not comply with practice guidelines. *Health Serv Res*. 2004;39:1429–48.
13. Boucher MC, Desroches G, Garcia-Salinas R, et al. Teleophthalmology screening for diabetic retinopathy through mobile imaging units within Canada. *Can J Ophthalmol*. 2008;43:658–68.

14. Sanmartin C, Gilmore J. Diabetes—prevalence and care practices. *Heal Reports*. 2008;19:59–64.
15. ICES Project No. 2015 0900 645 000. *Response to an Ontario Ministry of Health and Long-Term Care Applied Health Research Question*; 2015.
16. Leese GP, Boyle P, Zhiqiang F, Emslie-Smith A, Ellis JD. Screening uptake in a well-established diabetic retinopathy screening program the role of geographical access and deprivation. *Diabetes Care*. 2008;31:2131–5.
17. Lewis K, Patel D, Yorston D, Charteris D. A qualitative study in the United Kingdom of factors influencing attendance by patients with diabetes at ophthalmic outpatient clinics. *Ophthalmic Epidemiol*. 2007;14:375–80.
18. Maberley DAL, Koushik A, Cruess AF. Factors associated with missed eye examinations in a cohort with diabetes. *Can J Public Heal*. 2002;93:229–32.
19. Owsley C, McGwin G, Scilley K, Girkin CA, Phillips JM, Searcey K. Perceived barriers to care and attitudes about vision and eye care: Focus groups with older African Americans and eye care providers. *Invest Ophthalmol Vis Sci*. 2006;47:2797–802.
20. Klein R, Klein BEK, Moss SE, Cruickshanks KJ. The Wisconsin Epidemiologic Study of Diabetic Retinopathy XIV. Ten-year incidence and progression of diabetic retinopathy. *Arch Ophthalmol*. 1994;112:1217–28.
21. Klein R, Klein BE, Moss SE, Cruickshanks KJ. The Wisconsin Epidemiologic Study of Diabetic Retinopathy XV. The long-term incidence of macular edema. *Ophthalmology*. 1995;102:7–16.
22. Forbes A, Taylor HR. Screening for presence or absence of diabetic retinopathy. *Arch Ophthalmol*. 2011;129:435–44.
23. Shi L, Wu H, Dong J, Jiang K, Lu X, Shi J. Telemedicine for detecting diabetic retinopathy: a systematic review and meta-analysis. *Br J Ophthalmol*. 2015;99:823–31.
24. Kawaguchi A, Sharafeldin N, Sundaram A, et al. Tele-ophthalmology for age-related macular degeneration and diabetic retinopathy screening: a systematic review and meta-analysis. *Telemed e-Health*. 2018;24:1–8.
25. Rachapelle S, Legood R, Alavi Y, et al. The cost-utility of telemedicine to screen for diabetic retinopathy in India. *Ophthalmology*. 2013;120:566–73.
26. Nguyen HV, Tan GSW, Tapp RJ, et al. Cost-effectiveness of a national telemedicine diabetic retinopathy screening program in Singapore. *Ophthalmology*. 2016;123:2571–80.
27. Virgili G, Menchini F, Casazza G, et al. Optical coherence tomography (OCT) for detection of macular oedema in patients with diabetic retinopathy. *Cochrane Database Syst Rev*. 2015;1. CD008081.
28. Sa H, Alvarez-vidal A, Maldonado MJ, Moreno-montan J. Retinal thickness study with optical coherence tomography in patients with diabetes. *IOVS*. 2002;43:1588–94.
29. Harding S, Greenwood R, Aldington S, et al. Grading and disease management in national screening for diabetic retinopathy in England and Wales. *Diabet Med*. 2003;20:965–71.
30. Korobelnik J, Do DV, Schmidt-erfurth U, et al. Intravitreal aflibercept for diabetic macular edema. *Ophthalmology*. 2014;121:2247–54.
31. Wilkinson CP, Frederick L, Ferris I, et al. Proposed international clinical diabetic retinopathy and diabetic macular edema disease severity scales. *Ophthalmology*. 2003;110:1677–82.
32. Early Treatment Diabetic Retinopathy Study Research Group. Grading diabetic retinopathy from stereoscopic color fundus photographs: an extension of the modified Airlie House Classification ETDRS Report Number 10. *Ophthalmology*. 1991;98:786–806.
33. Brown JC, Solomon SD, Bressler SB, Schachat AP, DiBernardo C, Bressler NM. Detection of diabetic foveal edema: contact lens biomicroscopy compared with optical coherence tomography. *Arch Ophthalmol*. 2004;122:330–5.
34. The Early Treatment Diabetic Retinopathy Study Research Group. Photocoagulation for diabetic macular edema: Early Treatment Diabetic Retinopathy Study Report No. 4. *Int Ophthalmol Clin*. 1987;27:265–72.
35. Early Treatment Diabetic Retinopathy Study Research Group. Photocoagulation for diabetic macular edema. Early Treatment Diabetic Retinopathy Study Report Number 1. *Arch Ophthalmol*. 1985;103:1796–806.
36. Feder RS, Olsen TW, Prum BE, et al. Comprehensive adult medical eye evaluation preferred practice pattern guidelines. *Ophthalmology*. 2016;123:209–36.
37. Emptage NP, Kealey S, Lum FC, Garratt S. Preferred practice pattern: diabetic retinopathy. *Am J Ophthalmol*. 2014. Updated: www.aao.org/ppp.
38. Younis N, Broadbent DM, Vora JP, Harding SP. Incidence of sight-threatening retinopathy in patients with type 2 diabetes in the Liverpool Diabetic Eye Study: a cohort study. *Lancet*. 2003;361:195–200.
39. Klein R, Klein BEK, Moss SE, Cruickshanks KJ. The Wisconsin Epidemiologic Study of Diabetic Retinopathy: XVII the 14-year incidence and progression of diabetic. *Ophthalmology*. 1998;105:1801–15.
40. Mohamed Q, Gillies MC, Wong TY. Management of diabetic retinopathy: a systematic review. *JAMA*. 2007;298:902–16.
41. Misra A, Bachmann MO, Greenwood RH, et al. Trends in yield and effects of screening intervals during 17 years of a large UK community-based diabetic retinopathy screening programme. *Diabet Med*. 2009;26:1040–7.
42. Mitchell P. The prevalence of diabetic retinopathy: a study of 1300 diabetics from Newcastle and the Hunter Valley. *Am J Ophthalmol*. 1980;8:241–6.
43. Mansberger SL, Gleitsmann K, Gardiner S, et al. Comparing the effectiveness of telemedicine and traditional surveillance in providing diabetic retinopathy screening examinations: a randomized controlled trial. *Telemed J E Health*. 2013;19:942–8.
44. Nathoo N, Ng M, Rudnisky CJ, Tennant MTS. The prevalence of diabetic retinopathy as identified by teleophthalmology in rural Alberta. *Can J Ophthalmol*. 2010;45:28–32.
45. Cavallerano AA, Cavallerano JD, Katalinic P, et al. A telemedicine program for diabetic retinopathy in a veterans affairs medical. *Am J Ophthalmol*. 2005;139:597–604.
46. Boucher MC, Gresset JA, Angioi K, Olivier S. Effectiveness and safety of screening for diabetic retinopathy with two nonmydriatic digital images compared with the seven standard stereoscopic photographic fields. *Can J Ophthalmol*. 2003;38:557–68.
47. Ouyang Y, Heussen FM, Keane PA, Sadda SR, Walsh AC. The retinal disease screening study: prospective comparison of nonmydriatic fundus photography and optical coherence tomography for detection of retinal irregularities. *Invest Ophthalmol Vis Sci*. 2013;54:1460–8.
48. Virgili G, Menchini F, Dimastrogiovanni AF, et al. Optical coherence tomography versus stereoscopic fundus photography or biomicroscopy for diagnosing diabetic macular edema: a systematic review. *IOVS*. 2007;48:4963–73.
49. Davis MD, Bressler SB, Aiello LP, et al. Comparison of time-domain OCT and fundus photographic assessments of retinal thickening in eyes with diabetic macular edema. *Invest Ophthalmol Vis Sci*. 2008;49:1745–52.
50. Mackenzie S, Schmermer C, Charnley A, et al. SDOCT imaging to identify macular pathology in patients diagnosed with diabetic maculopathy by a digital photographic retinal screening programme. *PLoS One*. 2011;6:1–6.
51. Shu D, Ting W, Cheung CY, et al. Development and validation of a deep learning system for diabetic retinopathy and related eye diseases using retinal images from multiethnic populations with diabetes. *JAMA*. 2017;318:2211–23.
52. Chew EY, Schachat AP. Should we add screening of age-related macular degeneration to current screening programs for diabetic retinopathy? *Ophthalmology*. 2015;122:2155–6.
53. Ministry of Transportation: Medical Review. Basic Medical Standards: Vision Standards. Government of Ontario; 2017 www.mto.gov.on.ca/english/dandv/driver/medical-review/standards.shtml Published 2018. Accessed January 26.
54. Chou C, Cotch MF, Geiss LS, et al. Prevalence of diabetic retinopathy in the United States, 2005—2008. *JAMA*. 2010;304:2005–8.
55. Jani PD, Forbes L, Choudhury A, Preisser JS, Viera AJ, Garg S. Evaluation of diabetic retinal screening and factors for ophthalmology referral in a telemedicine network. *JAMA Ophthalmol*. 2017;135:706–14.
56. Ross SA, McKenna A, Mozejko S, Fick GH. Diabetic retinopathy in native and nonnative Canadians. *Exp Diabetes Res*. 2007;2007:76271.
57. Kanjee R, Dookeran RI, Mathen MK, Stockl FA, Leicht R. Six-year prevalence and incidence of diabetic retinopathy and cost-effectiveness of tele-ophthalmology in Manitoba. *Can J Ophthalmol*. 2017;52:S15–8.
58. Maberley D, Walker H, Koushik A, Cruess A. Screening for diabetic retinopathy in James Bay, Ontario: a cost-effectiveness analysis. *Can Med Assoc J*. 2003;168:160–4.
59. Jones S, Edwards RT. Diabetic retinopathy screening: a systematic review of the economic evidence. *Diabet Med*. 2010;27:249–56.
60. Rudnisky CJ, Tennant MTS, Weis E, Ting A, Hinz BJ, Greve MDJ. Web-based grading of compressed stereoscopic digital photography versus standard slide film photography for the diagnosis of diabetic retinopathy. *Ophthalmology*. 2007;114:1748–54.
61. Bursell SE, Cavallerano JD, Cavallerano AA, et al. Stereo nonmydriatic digital-video color retinal imaging compared with Early Treatment

Diabetic Retinopathy Study seven standard field 35-mm stereo color photos for determining level of diabetic retinopathy. *Ophthalmology*. 2001;108:572–85.
62. Scanlon P, Dirani M, Wijngaarden P. Screening for sight-threatening diabetic retinopathy: an update. *Egypt Retin J*. 2014;2:3–18.
63. Williams GA, Scott IU, Haller JA, Maguire AM, Marcus D, McDonald HR. Single-field fundus photography for diabetic retinopathy screening: a report by the American Academy of Ophthalmology. *Ophthalmology*. 2004;111:1055–62.
64. Philip S, Fleming AD, Goatman KA, et al. The efficacy of automated "disease/no disease" grading for diabetic retinopathy in a systematic screening programme. *Br J Ophthalmol*. 2007;91:1512–7.
65. Abràmoff MD, Folk JC, Han DP, et al. Automated analysis of retinal images for detection of referable diabetic retinopathy. *JAMA Ophthalmol*. 2013;131:351–7.
66. Soto-Pedre E, Navea A, Millan S, et al. Evaluation of automated image analysis software for the detection of diabetic retinopathy to reduce the ophthalmologists' workload. *Acta Ophthalmol*. 2015;93:e52–6.
67. Ting DSW, Cheung CYL, Lim G, et al. Development and validation of a deep learning system for diabetic retinopathy and related eye diseases using retinal images from multiethnic populations with diabetes. *JAMA*. 2017;318:2211–23.
68. Rahimy E. Deep learning applications in ophthalmology. *Curr Opin Ophthalmol*. 2018;29:254–60.
69. Grassmann F, Mengelkamp J, Brandl C, et al. A deep learning algorithm for prediction of age-related eye disease study severity scale for age-related macular degeneration from color fundus photography. *Ophthalmology*. 2018. [Epub ahead of print].
70. Devalla SK, Renukanand PK, Sreedhar BK, et al. A deep learning approach to digitally stain optical coherence tomography images of the optic nerve head. *Invest Ophthalmol Vis Sci*. 2018;59:63–74.
71. Lee CS, Baughman DM, Lee AY. Deep learning is effective for classifying normal versus age-related macular degeneration OCT images. *Ophthalmol Retin*. 2017;1:322–7.
72. Wintergerst MWM, Schultz T, Birtel J, et al. Algorithms for the automated analysis of age-related macular degeneration biomarkers on optical coherence tomography: a systematic review. *Transl Vis Sci Technol*. 2017;6:10.
73. Tufail A, Rudisill C, Egan C, et al. Automated diabetic retinopathy image assessment software: diagnostic accuracy and cost-effectiveness compared with human graders. *Ophthalmology*. 2017;124:343–51.
74. Rathi S, Tsui E, Mehta N, Zahid S, Schuman JS. The current state of teleophthalmology in the United States. *Ophthalmology*. 2017;124:1729–34.
75. Ministry of Health and Long-Term Care. OHIP Coverage for Eye Care Services Accessed January 26 www.health.gov.on.ca/en/public/publications/ohip/eyecare.aspx; 2018 Accessed January 26 .
76. Sheppler CR, Lambert WE, Gardiner SK, Becker TM, Mansberger SL. Predicting adherence to diabetic eye examinations development of the compliance with annual diabetic eye exams survey. *Ophthalmology*. 2014;121:1212–9.

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