
Teleophthalmology screening for diabetic retinopathy through mobile imaging units within Canada

Marie Carole Boucher,* MD, FRCSC; Gilles Desroches,† MD, FRCSC;
Raul Garcia-Salinas,‡ MD, FRCSC; Amin Kherani,§ MD, FRCSC; David Maberley,|| MD, FRCSC;
Sébastien Olivier,* MD, FRCSC; Mila Oh,¶ MD, FRCSC; Frank Stockl,** MD, FRCSC

ABSTRACT • RÉSUMÉ

Background: This study aimed to describe and measure the health results of a Category 3 teleophthalmology screening project for diabetic retinopathy (DR). Implemented through mobile screening imaging units located within pharmacies, the project had the goal of reaching unscreened diabetic patients in urban communities while lowering barriers to screening and saving medical resources.

Methods: Image capture of both eyes of 3505 known diabetic individuals was performed in the provinces of Quebec, British Columbia, Alberta, Manitoba, and Saskatchewan. A photographer performed fundus imaging, and a nurse used mild pupil dilation only when necessary to secure image quality. Screening was provided free of cost in the context of DR health days for DR screening. Through teleophthalmology, ophthalmologists proceeded with data and image interpretation, and timely referral when indicated.

Results: This project allowed the resumption of screening of over 38% of the cohort of known diabetics who reported never having undergone any eye examination with pupil dilation, and an additional 30% who reported not having been examined for over 2 years. All known diabetics were under the care of a general physician, and their mean diabetes duration, when known, was 8 years. DR pathology was found in 22.5% (20%–28%) of the cohort, 1.8% requiring urgent referral (within 30 days) as a result of the severity of the DR and 0.6% (0%–1.8%) requiring urgent referral for other reasons. An additional 8.7% (8.1%–19.5%) required ophthalmologic attention within 6 months because of DR and another 2.0% (0%–6.3%) between 6 months and 1 year. Incidental findings were found in 23%, the majority of which were related to cataract and dry macular degeneration. Urgent or significant incidental findings were found in 0.6% of the screened eyes. Pupil dilation with tropicamide 1% was deemed useful or necessary in 33.7% of the cohort. For 0.7% of the cohort, the images could not be interpreted because of poor image quality and for that reason had to be referred for a traditional dilated eye examination. Ophthalmologists were relieved of the examination of 85.6% of the screened diabetic individuals who benefited from screening without requiring a traditional ophthalmologic examination. On the other hand, ophthalmologists were required to provide urgent (within 30 days) services to 2% of the cohort, either because of threatening DR or because of incidental findings requiring rapid ophthalmologic attention.

Interpretation: This screening strategy for DR through mobile teleophthalmology imaging units efficiently lowered barriers to screening and created new screening opportunities for a large number of known diabetic individuals who were lost to the traditional health system. It has the potential to provide better outreach to diabetic populations while identifying individuals truly in need of the services of an ophthalmologist; at the same time it maximizes the use of limited ophthalmologic resources while favouring multidisciplinary collaborations. The significant incidental findings associated with screening highlight the need for ophthalmologic competencies during DR screening within a teleophthalmology approach. Further involvement of government health authorities is pivotal in embracing the opportunities provided by emerging technologies such as teleophthalmology and translating them into better outreach services to diabetic populations and thus better visual health results.

From *the Hôpital Maisonneuve-Rosemont, Université de Montréal, Montréal, Qué.; †the Ottawa Hospital, University of Ottawa, Ottawa, Ont.; ‡the Pasqua Hospital Eye Centre, University of Saskatchewan, Regina, Sask.; §the Rockyview Hospital, University of Calgary, Calgary, Alta.; ||the Vancouver General Eye Care Centre, University of British Columbia, Vancouver, B.C.; ¶the Royal Victoria Hospital, McGill University, Montréal, Qué.; and **the Misericordia Hospital, University of Winnipeg, Winnipeg, Man.

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Correspondence to Marie Carole Boucher, MD, Unité de recherche en ophtalmologie, Département d'ophtalmologie, Hôpital Maisonneuve-Rosemont, 5415 boul. de l'Assomption, Montréal QC H1T 2M4; mariecarole@gmail.com

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Contexte : Cette étude a pour objet de décrire et de mesurer les résultats en matière de santé d'un projet de dépistage de la rétinopathie diabétique (RD) par téléophtalmologie de catégorie 3. Le projet a été réalisé avec des appareils mobiles de dépistage par imagerie installés dans des pharmacies, le but étant d'atteindre les patients diabétiques non examinés des collectivités urbaines, en réduisant les obstacles au dépistage et en économisant les ressources médicales.

Méthodes : La capture d'images des deux yeux de 3505 personnes diabétiques a été effectuée dans les provinces de Québec, de la Colombie-Britannique, de l'Alberta, du Manitoba et de la Saskatchewan. Un photographe a capté l'imagerie du fond d'œil alors qu'une infirmière appliquait au besoin une légère dilatation de la pupille pour assurer la qualité de l'image. Le dépistage s'est fait sans frais dans le cadre de journées de la santé pour le dépistage de la RD. Par l'entremise de la téléophtalmologie, les ophtalmologistes ont procédé à l'interprétation des données et les images et, au besoin, à une consultation au moment opportun chez le spécialiste.

Résultats : Le projet a permis de reprendre le dépistage de plus de 38 % de la cohorte des diabétiques connus qui affirmèrent n'avoir jamais subi d'examen oculaire avec dilatation de la pupille et un autre 30 % qui rapportèrent n'avoir pas eu d'examen pendant plus de 2 ans. Les diabétiques connus étaient tous suivis par un omnipraticien et ceux qui le savaient avaient le diabète depuis 8 ans en moyenne. On a trouvé la pathologie de la RD chez 22,5 % (20 %–28 %) de la cohorte, 1,8 % ayant besoin de consultation urgente (moins de 30 jours) à cause de la gravité de la RD et 0,6 % (0 %–1,8 %) pour d'autres raisons. Un autre 8,7 % (8,1 %–19,5 %) avait besoin de soins ophtalmologiques en moins de 6 mois pour RD et un autre 2,0 % (0 %–6,3 %), entre 6 mois et 1 an. On a trouvé d'autres incidences dans 23 % des cas, la majorité se rapportant à la cataracte et à la dégénérescence maculaire sèche. Des données incidentes urgentes ou significatives ont été relevées chez 0,6 % des yeux examinés. La dilatation de la pupille avec de la tropicamide à 1 % s'est avérée utile ou nécessaire pour 33,7 % de la cohorte. Les images n'ont pas pu être interprétées dans 0,7 % des cas à cause de leur mauvaise qualité et on a dû référer ces cas à l'examen oculaire traditionnel avec dilatation. Les ophtalmologistes n'ont pas eu à examiner 85,6 % des personnes diabétiques, celles-ci n'ayant heureusement pas eu besoin du traditionnel examen ophtalmologique après le dépistage. Par ailleurs, les ophtalmologistes ont dû fournir des services d'urgence (en moins de 30 jours) à 2 % de la cohorte, à cause d'une RD menaçante ou d'incidences qui demandaient des soins urgents en ophtalmologie.

Interprétation : Cette stratégie de dépistage de la RD avec des unités mobiles d'imagerie par téléophtalmologie a réduit avec efficacité les obstacles au dépistage et créé de nouvelles possibilités de dépistage pour un grand nombre de personnes diabétiques qui étaient perdues dans le traditionnel système de santé. Elle permet de mieux joindre les populations diabétiques tout en pointant les personnes qui ont vraiment besoin des services d'un ophtalmologiste; elle permet aussi d'utiliser au maximum les ressources limitées en ophtalmologie, tout en favorisant la collaboration multidisciplinaire. Les incidences significatives associées au dépistage soulignent le besoin de compétences ophtalmologiques pendant le dépistage de la RD par téléophtalmologie. La participation accrue des autorités gouvernementales de la santé sera essentielle pour nous aider à saisir toutes les possibilités qu'offrent les nouvelles technologies comme la téléophtalmologie, à offrir de meilleurs services sur mesure aux populations diabétiques et à améliorer encore davantage la santé visuelle.

Diabetes mellitus remains the leading cause of blindness in the active population of all developed countries. It affects over 1.3 million Canadians, and 60 000 new cases are diagnosed each year.¹ Treatments for diabetic retinopathy (DR) are highly effective, economical, and available within the public health system; however, despite established comprehensive guidelines for systematic screening for DR, the adoption of yearly screening examination resists efficient implementation.^{2–4}

Factors such as a patient's age, type of diabetes, duration of disease, need of pupil dilation, and limitation in access to ophthalmologists affect the level of adherence to the recommended guidelines.^{2–8} Thus the use of a telehealth application providing screening opportunities for diabetic patients may offer an attractive alternative to overcome noncompliance with DR screening.

Photographic screening systems for DR with nonmydriatic or mydriatic digital cameras and their use within teleophthalmology systems in a valid environment for which standards have been well defined have been shown to be both sensitive and specific when compared with the gold standard of the 7-field stereoscopic standard 35 mm photographs.^{9–11} Digital retinal imaging offers the advantage of providing a permanent and objective record, immediate availability for review of image quality and content at the time of capture, and the possibility of safe, electronic transportation of the images; immediate availability also encourages sensitization of diabetic individuals to DR. Teleophthalmology systems as novel screening tools have been shown to benefit patients with diabetes,^{12–14} and the acceptance of screening for DR through teleophthalmology by the general diabetic population is high.⁹

An application of teleophthalmology that offers screening opportunities for diabetics while taking advantage of technology, providing community outreach, and using a multidisciplinary approach may better serve the diabetic community.

Our study was designed to describe and measure the health results of a Category 3 teleophthalmology¹² screening project for DR implemented through mobile screening imaging units located within pharmacies. The goal was to reach unscreened diabetic persons in urban populations by lowering barriers to screening and to save medical resources. Category 3 indicates a system that has been validated to identify Early Treatment Diabetic Retinopathy Study (ETDRS)-defined levels of nonproliferative DR (mild, moderate, or severe), proliferative DR (early, high-risk), and diabetic macular edema with sufficient accuracy to determine appropriate follow-up and treatment strategies. Category 3 validation allows patient management to match clinical recommendations based on clinical retinal examination through dilated pupils.

METHODS

Recruitment

Diabetic individuals were recruited through local newspaper and pharmacy advertising of screening to be held in pharmacies on specific health days. Advertising took place 2 weeks before screening, and appointments were made on a first-come basis. Screening was provided for free, funded through ethical partnerships developed with regional diabetic associations and pharmaceutical companies. A strict code of ethics prevented any direct or indirect solicitation or gift to diabetic patients. A mean number of 19 (median 15, range 5–30) known diabetic individuals/screening day underwent imaging procedures. If necessary, patients were referred to their own ophthalmologists. If the patient did not have an ophthalmologist, arrangements were made with local ophthalmologists to secure timely follow-up.

Screening and management process

Image capture of both eyes of diabetic patients was performed in urban communities of the provinces of Quebec, British Columbia, Alberta, Manitoba, and Saskatchewan through 3 mobile traveling units. A photographer performed fundus imaging, and a nurse provided DR education and mild pupil dilation only when necessary to secure image quality, with the exception of individuals with type 1 diabetes whose eyes were all dilated. Fig. 1 shows the teleophthalmology DR screening and management process. At the imaging site a consent form explaining the nature of the telemedicine examination and its limitations, specifically its strict use to perform DR screening and not to replace a standard ophthalmologic examination, was reviewed and signed. Visual acuity was measured in both eyes with a Snellen chart, and educational support about diabetic retinopathy

and its prevention through good glycemic and blood pressure control was provided; participants reported on their history of regular eye examinations. A medical history consisting of age, type and known duration of diabetes, presence of high blood pressure, insulin medication, and conditions and time of last eye examination was obtained. The names of all physicians involved in the care of the participants were recorded so that a DR status report could be sent to them. Corrected visual acuity was measured for each eye through stenopeic holes.

Imaging procedures

Digital fundus photographs were captured with a 45° nonmydriatic camera (Nidek NM-1000, Nidek, Fremont, Calif.) with a resolution of 1200 × 980 pixels. For type 2 diabetics the imaging protocol consisted of three 45° field photographs (nonstereoscopic photographs of the disc and superior temporal quadrant with a stereoscopic pair of images captured of the macula) through an undilated pupil. For type 1 diabetic patients, five 45° fields essentially equivalent to the seven 35° ETDRS fields were captured through pupils dilated with 1% tropicamide.

Image quality was assessed by the photographer at the time of capture and, in type 2 diabetics, if it was felt to be too low then imaging was performed with light pupil dilation, achieved with the use of 1% tropicamide instilled by the nurse with the appropriate explanations and precautions. Before any pupil dilation the nurse performed an evaluation of the anterior chamber depth with the muscle lamp test and had instructions to refrain from dilating in cases of narrow angles or if in doubt. All patients with pupil dilation were informed of the possible temporary vision blur following dilation and instructed to abstain from driving any motor vehicle during this period. They were also instructed to report any pain, eye redness, or persistent or increasing visual blur, and advised to consult an ophthalmologist if any of these symptoms, which could be associated with acute angle glaucoma, occurred. Patients whose image quality was persistently low or who refused dilation when it was felt necessary were invited to attend a timely traditional clinical ophthalmologic examination.

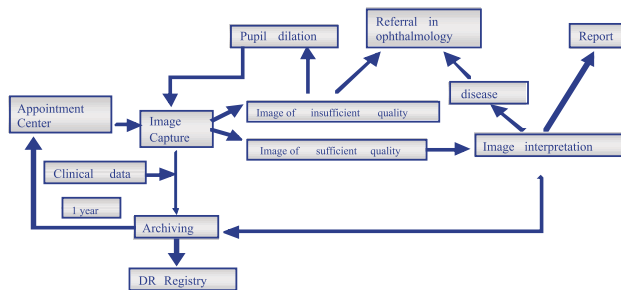


Fig. 1—Organization of the teleophthalmology health service model for the screening of diabetic retinopathy (DR).

Technology

The validity of a similar Category 3 teleophthalmology system with an identical screening strategy to that used in the present project has been measured as having a low (1.0%) false-negative rate and low (3.1%) false-positive rate.¹² However, higher image resolution (1280 × 980 pixels, 24 bit, vs 800 × 600 pixels, 24 bit) was used in the current project. The system in this project has previously been used as a Category 3 system and measured against the 7 standard stereoscopic 30° photographic fields, with pupil dilation, to match clinical recommendations of clinical retinal examination through dilated pupils with accuracy sufficient to determine appropriate follow-up and treatment strategies.¹² The system could identify very mild or worse retinopathy (≥ETDRS grade 20), mild or worse retinopathy (≥ETDRS grade 35), and moderate or worse retinopathy (≥ETDRS grade 43) with sensitivity values of 97.9%, 97.1%, and 53.3%, respectively, and specificity values of 81.3%, 95.5%, and 96.9%, respectively; with a screening threshold of mild (ETDRS grade 35), as used in this study, the system could correctly identify 100% of eyes with severe nonproliferative or proliferative retinopathy.

Data management and review

All data and 3.1 MB (24 bits/pixel) Tagged Image File (TIF) format images were uploaded without any compression as an encrypted digital file (128 bit RC4 data) to a double authentication protected secure Web server (Unix Couple Oracle servers, Retina Labs RD, Montreal, Que.) with verification of image transfer and noncorruption during transit.

The digital images were viewed on 47.5 cm or 52.5 cm (19" or 21") high-quality display cathode ray tube monitors (NEC MultiSync FE1250+, NEC Corporation, Tokyo, Japan) with screen resolutions set to 1280 × 1024 pixels (32 bit) with a 75 Hz refresh rate under conditions of ambient light similar to those of clinical fundus examination. Monitor brightness and contrast were set to the factory default.

All images were reviewed nonstereoscopically, actual pixels, at image capture resolution, first without and then with image enhancing (Adobe Photoshop 7.0, Adobe Systems Inc, San Jose, Calif.) by vitreoretinal specialists (Marie Carole Boucher, Raul Garcia-Salinas, Amin Kherani, Frank Stockl, or a specifically certified ophthalmologist), who were provided distance access to the images and clinical data under the same electronic transit conditions and through 2-point authentication. The images of 6 to 10 patients were reviewed per hour, depending on the presence and level of pathology. A senior ophthalmologist (Marie Carole Boucher) was responsible for the quality assurance and for the training and accreditation of all involved physicians.

The images were graded manually, and recommendations made according to the Scottish Diabetic Retinopathy

Grading Scheme 2003 (Table 1) with the Airlie House standard photographs available. Software for a display workstation (RetinaLabs RD) provided viewing of medical data along with the images and allowed the selection of images from an image sequence, as well as offering free text fields for special comments. This software made evaluation of image quality and macula status by the graders compulsory. The findings and recommendations of the ophthalmologists were uploaded to the central server with encryption for report generation.

Follow-up

Patients with moderate nonproliferative DR or with any DR within 2 disc diameters (DD) of the fovea were referred to the closest treating ophthalmologist. For all the others repeat imaging in 1 year or traditional eye examination with pupil dilation was recommended unless an incidental finding justified referral.

Within 2 weeks after screening, all patients were contacted by telephone and by mail for follow-up recommendations and provided with a timely ophthalmologic appointment when indicated. The use of software applications for clinical workflow management (RetinaLabs RD) ensured that priority was given to the most urgent cases and

Table 1—Classification of retinopathy*

Classification	Description	Outcome
Retinopathy		
R0	No DR	Rescreen 12 months
R1	Mild BDR; at least 1 dot hemorrhage or microaneurysm with or without hard exudates	Rescreen 12 months
R2	Moderate BDR; 4 or more blot hemorrhages (i.e., ≥AH standard photograph 2a) in 1 hemifield only (inferior and superior hemifields delineated by a line passing through the centre of the fovea and optic disc)	Rescreen 6 months (or refer to ophthalmologist if this is not feasible)
R3	Severe BDR; any of the following features: 4 or more blot hemorrhages (i.e., ≥AH standard photograph 2a) in both inferior and superior hemifields; venous beading (≥AH standard photograph 6a); IRMA (AH standard photograph 8a)	Refer to ophthalmologist
R4	Proliferative DR; any of the following features: new vessels; vitreous hemorrhage	Refer to ophthalmologist
R5	Enucleated eye	Rescreen 12 months (other eye)
R6	Inadequately visualised; retina not sufficiently visible for assessment	Technical failure, arrange alternative examination
Maculopathy		
M1 (observable)	Lesions within a radius of >1 but ≤2 disc diameters of the centre of the fovea; any hard exudates	Rescreen 6 months (or refer to ophthalmologist if this is not feasible)
M2 (referable)	Lesions within a radius of ≤1 disc diameter of the centre of the fovea; any blot hemorrhages; any hard exudates	Refer to ophthalmologist

*Scottish Diabetic Retinopathy Grading Scheme 2003.

Note: DR, diabetic retinopathy; BDR, background diabetic retinopathy; AH, Airlie House; IRMA, Intraretinal microabnormality.

that there was reliable follow-up and yearly recall of patients with negative screening results. This application ensured that, after 4 successive years of screening, patients would be directed to an ophthalmologist in order not to miss any other possible concurrent eye disease.

Reports of the screening results with a printed picture of each eye were generated at the data centre and sent to all physicians involved in the care of each diabetic individual, along with a note indicating the scheduled appointment date with an identified ophthalmologist. Although the quality of the printed images on the reports did not reflect the true quality of the images used for diagnosis they were found to add some useful information for the physician and the patient's file. All data were archived as a safety measure (10 years), 5 years more than legally required for regular medical information because of the recent advent of telemedicine; they were kept available to patients and physicians.

RESULTS

Sociodemographic data

From July 2003 to December 2005, 3505 known diabetic individuals responded to an invitation to be screened through mobile clinics located in pharmacies and traveling in urban and semiurban populations located in Quebec (2635 patients), British Columbia (331 patients), Alberta (260 patients), Saskatchewan (110 patients), and Manitoba (169 patients). More screening opportunities were possible in Quebec as the project originated in Quebec, which facilitated its funding and organization and incurred fewer traveling costs. A total of 182 pharmacies were involved. The demographic data for the cohort are shown in Table 2. Overall, 94.2% of the participants (87.7%–95.0% in the individual provinces) had type 2 diabetes. The median age of the screened patients was 63.0 (61.0–66) years, and

Table 2—Sociodemographic and compliance data of participants undergoing mobile teleophthalmology screening for diabetic retinopathy

Measure	Total (n = 3505)	Quebec (n = 2635)	British Columbia (n = 331)	Alberta (n = 260)	Saskatchewan (n = 110)	Manitoba (n = 169)
Sociodemographic						
Male, % (n)	49.1 (1720)	49.6 (1308)	50.7 (168)	60.8 (158)	40.06 (44)	24.8 (42)
Median age, y	63.0	63.0	62.5	61.0	66.0	63.0
Type 2 diabetes, % (n)	94.2 (3301)	95.0 (2503)	93.7 (310)	87.7 (228)	92.7 (102)	93.5 (158)
Known diabetes duration, mean y (median)	8.0 (5.0)	7.6 (5.0)	8.8 (5.5)	8.8 (6.0)	9.0 (6.0)	8.0 (7.0)
Insulin therapy, % (n)	35.9 (1258)	40.3 (1061)	20.2 (67)	23.8 (62)	29.1 (32)	21.3 (36)
High blood pressure medication, % (n)	57.3 (2009)	56.5 (1488)	60.6 (201)	56.2 (146)	67.3 (74)	59.2 (100)
Compliance*						
Never any exam, % (n)	38.7 (1358)	41.6 (1095)	23.3 (77)	29.6 (77)	40.0 (44)	38.5 (65)
Last exam >2 years, % (n)	30.1 (1054)	28.9 (762)	32.6 (108)	31.9 (83)	29.1 (32)	37.3 (63)
Conditions of imaging						
Pupil dilation with 1% tropicamide, % (n)	33.7 (1182)	33.0 (869)	25.1 (83)	43.1 (112)	35.5 (39)	46.7 (79)

*Compliance with screening: last eye examination with pupil dilation

Table 3—Screening results of teleophthalmology screening for diabetic retinopathy

Results	Total (n = 3505)	Quebec (n = 2635)	British Columbia (n = 331)	Alberta (n = 260)	Saskatchewan (n = 110)	Manitoba (n = 169)
Presence of DR, % (n)	22.5 (755)	20.2 (531)	28.4 (94)	27.7 (72)	20.0 (22)	21.3 (36)
Total urgent referral (within 30 days), % (n)	2.4 (85)	2.3 (60)	2.7 (9)	4.2 (11)	0.9 (1)	2.4 (4)
Urgent referral for DR (within 30 days), % (n)	1.8 (63)	1.8 (47)	1.8 (6)	3.1 (8)	0.9 (1)	0.5 (1)
Other referral for DR within 6 months, % (n)	8.7 (332)	8.8 (232)	10.9 (36)	8.5 (22)	8.1 (9)	19.5 (33)
Referral for DR between 6 months and 1 year, % (n)	2.0 (62)	1.4 (36)	6.3 (21)	1.9 (5)	—	—
Total referral for pathology other than DR, % (n)	2.8 (100)	2.7 (71)	5.4 (18)	1.9 (5)	—	3.6 (6)
Referral for insufficient imaging, % (n)	0.7 (25)	0.8 (20)	1.2 (4)	—	0.9 (1)	—
Ophthalmological examinations saved, % (n)	85.6 (3002)	87.2 (2299)	79.1 (250)	79.2 (206)	80.1 (89)	78.1 (132)

Note: DR, diabetic retinopathy.

49.1% (24.8%–60.8%) of the cohort were male. The mean known duration of diabetes was 8.0 (median 5.0) years. A mean of 35.9% (SD 8.2, range 20.2%–40.3%) of the cohort were receiving insulin therapy, and a mean of 57.3% (SD 4.5, range 56.2%–67.3%) were being treated with high blood pressure medication. The ethnic background of the population was not evaluated in the project.

Overall, 68.8% (61%–76%) of the cohort admitted noncompliance with Canadian DR screening guidelines: 38.7% (23.3%–41.6%) of all screened diabetic patients reported never having had any ophthalmologic examination or eye examination with pupil dilation, and an additional 30.1% (28.9%–37.3%) stated that they had not been examined for over 2 years.

Screening results

Table 3 presents the screening results obtained with mobile imaging sites in the 5 Canadian provinces.

DR pathology was found globally in 22.5% (20.2%–28.4%) of the cohort, 1.8% (0.5%–3.1%) requiring urgent referral (within 30 days) for severe (R3) or proliferative (R4) disease or for exudates or blot hemorrhages within ≤ 1 DD of the centre of the fovea (M1 maculopathy), and a total of 2% (0.9%–4.2%) requiring urgent referral for other reasons. An additional 8.7% (8.1%–19.5%) required ophthalmologic attention within 6 months because of moderate (R2) disease or the presence of exudates within >1 but ≤ 2 DD of the centre of the fovea (M1), and another 2% (0%–6.3%) needed attention in 6 months to 1 year for mild (R1) disease.

There were some incidental findings in 810 (23.1%) of the 3505 diabetic individuals of the cohort, and these are shown in Table 4. The majority were related to the presence of some degree of cataract (395 eyes), dry age-related macular degeneration (226 eyes), the presence of fine drusen (209 eyes), choroidal naevi (98 eyes), peripapillary atrophy (72 eyes), and premacular cellophane membrane (58 eyes). Rarer but significant findings were diagnosed, such as branch vein occlusion in 8 eyes, suspicion of glaucoma in 7 eyes, suspected subretinal neovascular membrane in 6 eyes, arterial emboli in 5 eyes, active choroiditis in 3 eyes, and 1 possible disc edema. Screening led to referral to ophthalmology services for reasons not related to the DR in 2.8% (0%–5.4%) of the cohort. Incidental findings requiring urgent ophthalmologic attention were found in 0.6% (0%–1.8%) of the cohort. The required follow-up ophthalmologic examinations with a local ophthalmologist informed of the project were organized in a timely manner, and all patients were contacted both by telephone and by letter informing them of the time and date of the appointment. The study did not measure the number of individuals who missed their appointment with the ophthalmologist. After being informed of the project, all but 1 ophthalmologist graciously agreed to take under their care the diabetic individuals in their community in need of

follow-up for DR. The patient whose ophthalmologist did not agree was provided care by another ophthalmologist in the same community.

In 33.7% (25.1%–46.7%) of the cohort light pupil dilation with 1% tropicamide was judged useful or necessary by the photographer to secure good image quality. No individuals refused pupil dilation when it was judged to be indicated; 0.7% (0%–1.2%) of the cohort was referred to ophthalmology for complete eye examination with pupil dilation because the study ophthalmologist judged the images of sufficiently poor quality for interpretation in at least 1 eye at the time of image and data interpretation. A higher rate of pupil dilation (46.7%) was felt to be needed by the photographer in Manitoba. Although the study did not take into account the ethnic origins of the patients, a significant number of screened patients from Manitoba were of Amish and First Nations origin, which may explain this higher rate.

Efficiency of the teleophthalmology approach

In this teleophthalmology setting, the screening for DR of 3505 diabetic individuals led to a 1-year referral to an ophthalmologist for 16.1% (11%–21%) of the cohort:

Table 4—Incidental findings* from teleophthalmology screening for diabetic retinopathy (n = 810)

Results	No. of eyes OD/OS
Some presence of cataract	195/200
Dry AMD	124/102
Small drusen	107/102
Choroidal naevus	49/49
Peripapillary atrophy	35/37
Cellophane maculopathy	31/27
Myelinated fibres	13/15
Disc anomaly	13/9
Scars of inactive choroiditis	7/10
Angioid striae	5/6
Asteroid hyalosis	2/8
Myopic retinopathy	5/4
Branch vein occlusion (3 recent, 2 old/1 recent, 2 old)	5/3
Glaucoma suspicion	4/3
Possible subretinal neovascular membrane	3/4
Choroidal folds	4/3
Disciform macular scar	0/7
Supect naevus or choroidal tumour	5/1
Hematologic concern	2/4
Hemorrhages secondary to high blood pressure	2/4
Embolus	2/3
Retinal midperipheral dystrophy	2/2
Vascular sheathing	2/1
Active choroiditis	2/1
Macular hole	1/2
Possible disc edema	1/0
Other maculopathy	0/1

*Single or multiple incidental findings could occur in one eye or in both eyes of a single patient.
Note: AMD, age-related macular degeneration.

within 1 year, 12.5% (11.5%–20.9%) of the study participants were referred because of a positive DR screening, 2.8% (0%–5.4%) because of other ophthalmologic findings, and 0.7% (0%–1.2%) because of insufficient image quality for valid interpretation. Of screened diabetic individuals, 83.4% (78.1%–87.2%) benefited from DR screening without requiring a traditional ophthalmologic examination. On the other hand, this approach meant that ophthalmologists were required to provide urgent (within 30 days) services to 2.4% (85 patients) of the cohort either because of threatening DR or because of incidental findings requiring rapid ophthalmologic attention.

INTERPRETATION

The challenge

Despite substantial efforts to educate both patients and physicians, this study highlights the persistent high rate of diabetic individuals throughout the different Canadian areas in this study who are not compliant with the Canadian guidelines that recommend yearly eye examination. Over 68% of the cohort admitted noncompliance with Canadian DR screening guidelines, a mean of 30.1% reporting not having had a dilated eye examination for over 2 years and another 38.7% reporting never having had any dilated eye examination. All the diabetic individuals of the cohort were under the care of a general physician and some also under the care of an endocrinologist. The study cohort had a mean diagnosed diabetes duration of 8.0 years with a median of 5.0 years. Other studies have observed a similar rate of noncompliance in diabetic populations.^{15–21}

Though screening for DR is widely recognized as both good clinical practice and cost-effective health care, a majority of diabetic patients do not comply with examination guidelines for multiple reasons, including the absence of any symptom until the disease is very advanced and ignorance of eye disease in a context of multiple other health problems associated with diabetes.²² Other factors of an organizational kind, such as difficult access to ophthalmologic resources, represent a major logistic problem partly because the requirements of mass screening through regular ophthalmologic settings largely exceed the medical and financial resources available.^{9,23} In addition, the dissemination of treatment guidelines for DR has been assessed as having little impact on health care management, or referral or treatment behaviours of physicians.²⁴

The majority of the population of Canada live in large urban centres, located primarily in the south of the country,²⁵ and DR is known to be prevalent in urban populations.²⁶ Waiting times to see an ophthalmologist can be lengthy, although travel distances are short. A study of a diabetic population in a Montreal suburb revealed that 14% of the noncompliant group who were aware of the DR guidelines stated inaccessibility and difficulty in obtaining an appointment as the reason for not following up on a screening examination.⁹

Fundus examination for DR requires pupil dilation and sufficiently trained examiners. If these conditions are not fulfilled, missed detection of 100% of macular edema and of 50% of proliferative disease can result.²⁷

It is highly unlikely that general practitioners and endocrinologists will become more involved in screening the eyes of diabetic patients, given the obstacles of pupil dilation, technical difficulty, the time demanded by this examination, and the multisystemic health problems of their diabetic patients, more so in this era of insufficient medical resources and high demand for medical services with the aging population.²⁸

Through their capacity to lower barriers to screening, such as access and pupil dilation, teleophthalmology systems have the potential to be of benefit as a screening tool for patients with diabetes, particularly given the limited number and availability of eye care specialists in Canada and the increase in the prevalence of DR. The high acceptance of screening for DR through teleophthalmology by a general diabetic population⁹ provides favourable conditions for its implementation.

Reaching the diabetic community

The challenge in establishing effective screening for DR, in addition to providing accurate diagnosis and timely treatment, lies in reaching diabetics using simple and cost-effective modalities.²⁹ In a traditional clinical setting diabetics have to travel to the clinic. The current vision care system relies heavily on self-referral to identify individuals in need of ophthalmologic care, and only those individuals who are strongly motivated to seek council or care access the health system. Telehealth applications have the potential to create new screening opportunities for diabetics. As well, they can be set up anywhere in a professional manner identical to that of a traditional clinical setting. While a clinical setting is certainly more traditional and user-friendly for health care professionals, teleophthalmology systems can be positioned strategically in places where diabetics congregate on a regular basis, such as a pharmacy.

At the moment, government health priorities and limited available health funding preclude the ideal of reaching most diabetics for DR screening, though this may eventually become possible through telemedicine. In that context the project has implemented an alternative, teleophthalmology, approach funded by regional diabetic associations and pharmaceutical companies in order to reach diabetics, free of cost. All detected DR of \geq ETDRS grade 35 severity or any DR within 1 DD of the fovea was referred to an ophthalmologist, making the sensitivity of this system very high.¹² All screened patients were notified of their results and of their timely follow-up if needed, and were scheduled to see an ophthalmologist, ensuring that there was efficient and appropriate follow-up for those with retinopathy. This approach, with technologies used within recognized standards (modalities of imaging: site, number, quality; transmission: integrity, security, confi-

dentiality; and interpretation: screen, qualification of reader), has been validated and implemented in some public health systems such as those of the United Kingdom³⁰ and France.³¹

Among the many other elements that must be evaluated in order to translate a screening strategy into benefits for patients most at risk of vision loss from DR—such as patient compliance, image quality, reliability and reproducibility of image assessment, constraints on clinic and consultant availability, cost-effective implementation, and outcomes—screening site location is a variable that remains to be better understood. Through the very significant proportion (68.8%) of known diabetics who were lost to the traditional eye care system and who were retrieved through this approach, the study has shown that a teleophthalmology system positioned strategically in the vicinity of diabetic individuals, such as in pharmacies, offers an effective technological and environmental interface between these individuals and the vision care system. It has highlighted the capacity and efficiency of these screening site location choices to efficiently reach diabetic individuals and to identify those in need of follow-up or treatment; this is illustrated by the analysis of the 38.7% subgroup that claimed never to have had any dilated eye examination (Table 2): in this group there was a significant rate of detected DR (12.2%, 5.0%–13.8%), as well as a need for ophthalmologic referrals for DR within 6 months in 5.7% (1.9%–9.1%). The poor rate of compliance with screening guidelines measured in this study agrees with the rate measured by Health Canada,³² which found that 62.4% of self-reported adults with diabetes in 1998–1999 had had an eye examination in the previous year. Given the self-reported nature of diabetes, these numbers possibly understate the true rate measured.

DR screening results

The presence of DR detected in 22.5% of the cohort, as well as the sight-threatening DR found in 1.8%, is in accordance with the reported expected DR and the untreated sight-threatening prevalence with the diabetic population.^{33,34} In all provinces where the study was performed, a mean of 85.6% (SD 3.7%, range 78.1%–87.2%) of the diabetics without any or with minimal pathology detected at initial screening did not require special care from an ophthalmologist and could

continue to be monitored by annual teleophthalmology screening. In Manitoba, a higher rate (19.5%) of the screened diabetics were referred to an ophthalmologist within 6 months because of a higher rate of moderate background DR. This could reflect the higher rate (37.3%) of the screened diabetics who had previously not been compliant with screening for over 2 years in that province. Again, similar findings were found in all provinces included in this study. While providing timely follow-up this approach has the merit of allowing an efficient usage of specialized human medical resources.

As shown in Table 5, of the group of diabetic individuals who admitted to noncompliance with the screening guidelines (68.8%), the 38.7% subgroup that claimed never to have had any dilated eye examination (Table 2) showed a significant rate of DR (12.2%, 5.0%–14.3%) with total ophthalmologic referrals for DR recommended within 6 months in 5.7% (1.9%–9.1%), again emphasizing the effectiveness of the screening strategy used in this study.

While providing community outreach, this project favoured a multidisciplinary approach by offering easier access to DR screening for patients and feedback to general physicians and endocrinologists through the detailed DR status reports communicated. It also provided a new opportunity to better sensitize patients to good glycemic and blood pressure control through its educational component, indicating that screening for DR is important for the detection not only of sight-threatening retinopathy but also of any retinopathy, so that particular efforts can be made to improve blood pressure and glycemic control.³⁵

A significant (23%) proportion of incidental findings (Table 4) was detected, of which 0.6% (44 eyes) were assessed as urgent. Most of the incidental findings were related to the presence of cataract to some degree and to dry age-related macular degeneration. However, the relatively high rate of incidental findings and in particular the urgent or significant, albeit infrequent, ones underlines the necessity for established ophthalmologic expertise to perform and supervise image interpretation so that incidental and urgent pathologies can be recognized and referred. All the patients were advised personally by telephone and also by letter of the appointment with the ophthalmologist in their area, but we have no data as to how many people missed their appointment. Further study is needed to assess compliance with referral.

Table 5—Results of teleophthalmology screening of diabetic participants who had never had previous dilated eye examination

Results	Total (n = 1358)	Quebec (n = 1095)	British Columbia (n = 77)	Alberta (n = 77)	Saskatchewan (n = 44)	Manitoba (n = 65)
Presence of DR, % (n)	12.2 (166)	5.0 (133)	13.0 (10)	14.3 (11)	6.8 (3)	13.8 (9)
Urgent referral for DR (within 30 days), % (n)	1.3 (18)	0.5 (14)	—	1.3 (1)	2.3 (1)	1.2 (2)
Other referral for DR within 6 months, % (n)	4.4 (60)	1.4 (38)	7.8 (6)	2.6 (2)	6.8 (3)	6.5 (11)

Note: DR, diabetic retinopathy.

Although nonmydriatic cameras were used in this study, dilation was deemed useful or necessary in 33.7% (25.1%–46.7%) of the cohort. Light dilation with 1% tropicamide was then performed by the nurse with all of the appropriate precautions to detect possible acute angle closure glaucoma. Under these conditions, image quality was insufficient in at least 1 eye of only a very small number of patients (25 individuals, 0.7%, 0%–1.2%), demonstrating that a nonmydriatic imaging approach using light dilation only when necessary is efficient to reach most diabetics in these populations while lowering another barrier to screening, such as reluctance to undergo pupil dilation.⁶ In the context of the high rate of pupil dilation measured in this study, the time required to select the individuals in need of pupil dilation may be questioned and universal dilation suggested by some. Although none of the individuals in need of pupil dilation refused it, over 65% benefited from the absence of the inconvenience created by pupil dilation, which is a known barrier to screening.⁶ In Manitoba, a higher rate of pupil dilation was measured (46.7%). Although there are no precise data on the ethnic origins of the participants, the screened population in Manitoba included a significant number of persons of Amish and First Nations origin, which might explain the higher need for pupil dilation. Dilation performed by a health professional, as is currently required by medicolegal authorities, also significantly increases the cost of screening. New legislation, such as that of the national U.K. DR teleophthalmology screening program, which now permits specially accredited photographers to proceed with 1% tropicamide dilation with the appropriate precautions,³⁶ may eventually help alleviate the costs of mass screening for DR.

The low proportion of patients (0.7%) in whom images could not be interpreted because of poor image quality in at least 1 eye and who for that reason had to be referred for a traditional dilated eye examination underlines the effectiveness of this teleophthalmology system in a mass screening strategy for DR.

No intraocular pressure was measured in this screening project, which aimed strictly at reaching unscreened diabetic patients lost to the traditional health care system. All participants were made aware that the screening protocol did not replace a complete eye examination or constitute glaucoma screening. Nevertheless, it was useful in identifying suspected glaucoma in 7 eyes of 3505 patients (0.2%), a lower rate than the expected prevalence of glaucoma in people with diabetes (3.7%–11.8%).³⁷ One-off screening, such as that provided in this study, is certainly insufficient in a screening strategy for DR if screening is not repeated regularly; neither would it provide adequate glaucoma detection unless the intraocular pressure was taken and (or) other optic nerve imaging devices were added. In order not to miss any other possible concurrent eye disease, a regular screening program would need to include occasional traditional eye care examination.

Through the computer applications used in this study, significant epidemiologic data can be generated establishing correlations between patients' age, diabetes duration, glycemic and blood pressure control, degree of DR severity in general or within specific areas or populations. If used on a larger scale within a public health system these data could constitute another source of prospective information for an eventual DR registry and for better planning of health resource allocations.

Cost and funding

Through partnerships developed with regional diabetic associations and pharmaceutical companies, screening and DR education were provided free to diabetic patients within the mobile screening units. Until a screening program for DR is publicly funded, this approach has the advantage of eliminating cost as a barrier to screening and providing free access to screening for all those with diabetes at a location where they are likely to congregate. Yearly systematic recall of eligible patients establishes a continuous process at regular intervals and is an important element in an effective screening program. This current teleophthalmology strategy has the disadvantage of providing only one-off screening; however, if it were repeated regularly at the same site it could eventually reach most diabetics within a community. This problem will continue as long as the strategy depends on the good will of private funders and until systematic screening for DR is publicly funded.

Screening costs for eye disease and particularly for diabetic retinopathy are lower than those of conventional eye examination by an eye care specialist for those living in remote locations.^{38–40}

In the urban settings of this study the cost of this teleophthalmology service amounted to \$100 per retinal examination excluding the cost of the camera. Although more in-depth cost analysis is needed, this cost appears to compare favourably with that of the traditional clinic system, in which there are additional costs of medical expertise, fundus photography, files, archiving, nursing, appointment and secretarial staff, and housing, and furthermore the maximum use is being made of ophthalmologic human resources.

It is also important to recognize the vulnerability of the diabetic population and to ensure that all partnerships be governed by a strict code of ethics forbidding any form of gift, privilege, or solicitation to any of the screening participants, as was the case in this project. Further involvement of government health authorities in such a technology-based approach to screening for DR would better serve the needs of diabetics while complementing the current uneven and fragmented health services, in which efforts are often duplicated.

Conclusion

This study established that screening for DR in mobile teleophthalmology settings located in pharmacies in urban settings efficiently lowers barriers to screening for DR and creates new screening opportunities for a large number of

known diabetic individuals who were lost to the traditional health system. It has been shown to have the potential to provide better outreach to diabetic populations while identifying individuals truly in need of the services of an ophthalmologist, and to make maximum use of ophthalmologists while favouring multidisciplinary collaborations. Further study is needed, however, to assess the number of people who, once screened as positive, would not follow up on their appointment with an ophthalmologist. Significant incidental findings associated with screening highlight the need for experienced ophthalmologic competencies in the teleophthalmology approach. Further involvement of government health authorities is pivotal in embracing the opportunities presented by emerging technologies such as teleophthalmology, translating them into better outreach for diabetic populations, and achieving better visual health results.

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