# Tele-retina screening of diabetic retinopathy among at-risk populations: an economic analysis

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**ABSTRACT •**

**Objectives:** To assess the cost-effectiveness of the pilot Toronto tele-retina screening program in comparison with existing standard of care (SOC) diabetic retinopathy (DR) screening for patients with diabetes mellitus and in a simulated Pan-Ontarian cohort.

**Methods:** Decision trees were constructed to compare tele-retina to SOC in the pilot and Pan-Ontarian cohort. Cost-effectiveness was assessed as cost per case detected (true-positive) and cost per case correctly diagnosed (true-positive and true-negative results).

**Results:** Pilot program screening costs were $95.77 and $137.56 for tele-retina and SOC, respectively. In the base-case analysis, cost per case correctly detected was $379.06 with tele-retina and $985.56 with SOC, and the cost per case correctly diagnosed was $109.29 and $315.22, respectively. In the sensitivity analysis, cost per case correctly detected was $467.29 with tele-retina and $894.93 with SOC, and the cost per case correctly diagnosed was $136.88 and $250.35, respectively. Pan-Ontarian screening costs were $57.58 and $137.56 for tele-retina and SOC, respectively. The cost per case correctly detected was $281.10 with tele-retina and $982.00 with SOC, and the cost per case correctly diagnosed was $82.21 and $314.14, respectively. For both pilot and Pan-Ontarian sensitivity analyses, tele-retina remained the dominant strategy (ICER <0).

**Conclusions:** Findings from this study suggest that tele-retina is a more cost-effective means of screening for diabetic retinopathy than the SOC in urban and rural underscreened communities. Subsequent economic studies should focus on evaluations that consider the impact of tele-retina on the prevention of severe vision loss in underscreened urban and rural communities.

Diabetic retinopathy (DR) is a sight-threatening complication in patients with diabetes mellitus that is often asymptomatic in the initial stages.[1] In 2016, approximately 500 000 Canadians reported some form of retinopathy, out of which 100 000 reported severe retinopathy, diabetic macular edema, or both, and 6000 were already blind from the disease.[2]

The prevalence of vision loss in Canada is expected to increase nearly 30% in the next decade.[3] The National Coalition for Vision Health noted that direct and indirect health care costs of vision loss in Canada for 2011 were estimated at $15.8 billion/year and projected to increase to $30.3 billion/year by 2032.[4] In addition to these costs, the Canadian National Institute for Blindness estimated the cost of associated complications of vision loss—falls $25.8 million, depression $175.2 million, and hip fractures $101.7 million—and the cost of nursing home admissions $713.6 million.[5]

Most vision loss from diabetic retinopathy can be avoided by early detection and treatment. Screening examinations every 1−2 years are recommended for all patients with diabetes and have been shown to reduce the incidence of vision loss or blindness.[6,7] Yet, approximately 50% of patients with diabetes do not receive examinations according to recommended guidelines.[8]

The Toronto tele-retina pilot program was created to optimize the screening of DR in primary care. With the anticipated increase in the need for DR screening in Canada, tele-retina services may facilitate appropriate eye care delivery to diabetic underscreened populations, while addressing the access to care and cost issues facing the Canadian health care system. The Toronto tele-retina program demonstrated that a staggering 37% of all included patients have never had an eye examination and 27% of the screened samples were diagnosed with DR.[9] Based on the successful pilot of tele-retina in Toronto, the program is being scaled up to provide eye care to additional diabetic underscreened populations.

However, the costs and cost-effectiveness of this program have not yet been reported. Herein, the objective of this study was to provide the cost-effectiveness of the Toronto tele-retina program in comparison to the standard of care (SOC) and to provide an estimate of the program that is now being expanded across the province using a Pan-Ontarian cohort.



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## Methods

### Study Setting and Population

The Toronto tele-retina screening program is offered in partnership with 7 primary care organizations with a population focus or located in low-income communities with a high prevalence of diabetes and low DR screening rates. A total of 566 patients were screened and sites were in urban (Anishnawbe Health Toronto, South Riverdale Community Health Centre [SRCHC], Parkdale Community Health Centre, Flemingdon Park Community Health Centre and Scarborough Academic Family Health Team) and rural (Moose Deer Point First Nations Health Clinic and Wahta Nursing Station) settings.[9,10] Tele-retina services are covered under the Ontario Health Insurance Plan (OHIP); tele-retina also provided services to those individuals residing in Ontario who are unable to obtain government insurance coverage (non-OHIP-insured patients) including those residing illegally, those new to Canada awaiting coverage, and those so marginalized that they may struggle to have the identification and home address required to obtain OHIP.[9,11]

Tele-retina inclusion criteria were (*i*) diagnosis of diabetes (type I and type II); (*ii*) referral from a physician or nurse practitioner (as of May 1, 2015, specialists can accept referrals from nurse practitioners); and (*iii*) if the patients do not already have an eye care provider, and have not had an eye examination that involves dilatation of pupils within the past year. For a full description of study methods, refer to Felfeli et al.[9]

### Decision-Tree Model

Decision trees were constructed to compare in-person examination for screening of DR (SOC) versus tele-retina pilot program. Decision trees (Fig. 1) were constructed for both pilot program and Pan-Ontarian scenario.

Our analysis was restricted to the correct detection and diagnosis of DR cases. We did not incorporate treatment effects and disease progression into the model because of limited up-to-date evidence for this population. The 2 screening programs were modelled to run concurrently for 5 years, with outcomes evaluated over 1 year. Tree Age Pro Suite 2017 was used for constructing decision trees and for analyses.

### Interventions

*Tele-retina screening.* After being referred to the program by the primary care provider the patient is contacted by the tele-retina program to schedule an appointment (~1 h duration) at the mobile screening clinic.[11] At the time of screening, a clinic (ophthalmic) assistant completes targeted medical history, measures visual acuity and intraocular pressure, and dilates the pupils before performing digital colour imaging and optical coherence tomography (OCT). The encounter details (or appointment details) and images are uploaded to a secure server using Ontario Telemedicine Network. Images are graded for level of DR or other retinal disease by a retina specialist (M.H.B). Reports with management recommendations are then sent to SRCHC program coordinators, who are responsible to follow-up with the referring clinician.

*Standard of care screening (SOC).* The SOC was defined as a fundus examination with pupil dilation performed by a primary care eye specialist (optometrist or ophthalmologist). Patients with positive results would be referred to a retina specialist, as coordinated by the primary care provider for comprehensive eye examination with angiography and OCT.

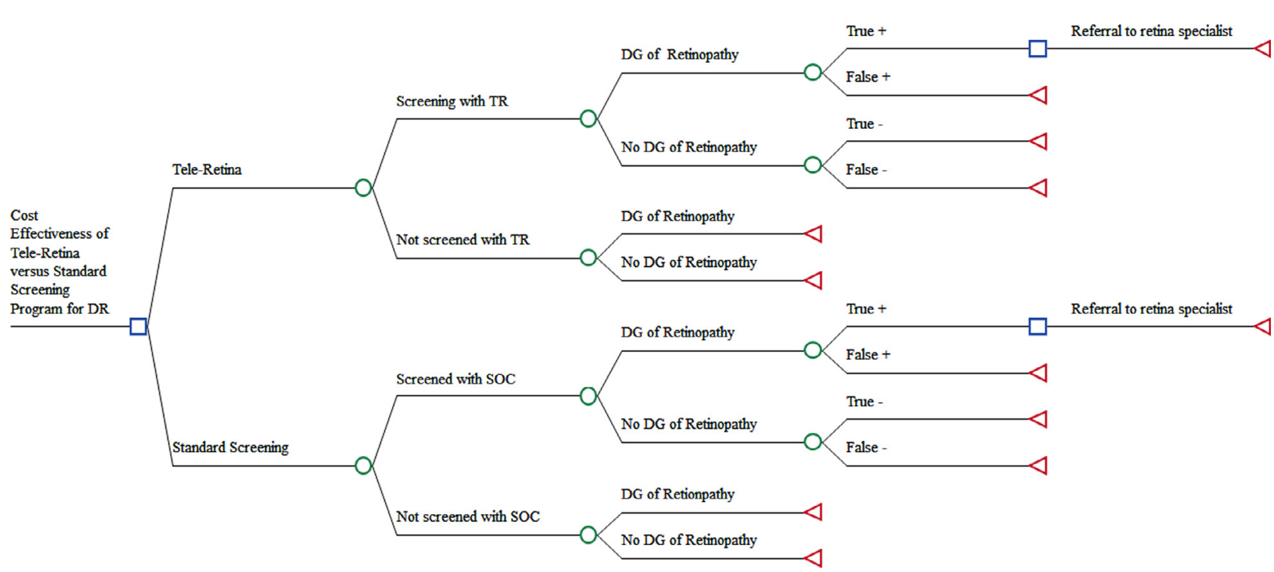


**Fig. 1—Decision tree of tele-retina versus standard of care screening (SOC) for diabetic retinopathy (DR). Decision tree illustrating the possible consequences, chance of event outcomes, resource costs, and utility of using tele-retina (TR) versus in-person SOC to measure DR.**

**Table 1—Base-case model input parameters (variables and ranges)**

| Variable | Value (Range) |
|---|---|
| Eye examination rate with pilot tele-retina program (M.H.B) | 0.80 |
| Eye examination rate with current practice (in-person examination)[17] | 0.55 |
| Prevalence of any diabetic retinopathy in Canada[8,17] | 0.225 (0.169–0.281) |
| Tele-retina screening variables (M.H.B) | |
| Sensitivity (true-positive) | 0.95 (83–98) |
| Specificity (true-negative) | 0.85 (0.89–0.98) |
| Reference program screening variables[1,8,17] | |
| Sensitivity (true-positive) | 0.75 (0.67–0.83) |
| Specificity (true-negative) | 0.82 (0.79–0.86) |
| Diagnosis of diabetic retinopathy in tele-retina[9] | 0.27 |
| Diagnosis of diabetic retinopathy in the standard of care[9] | 0.34 |
| Relative utility for individuals with diabetes[15] | 0.85 |
| Relative utility for individuals with diabetic retinopathy[15] | 0.77 |

### Identification of Model Probabilities, and Utilities

The probabilities used in the base-case model are shown in Table 1. We obtained an estimate of the diagnostic performance of tele-retina based on expert opinion (M.H.B). The diagnostics of the SOC were taken from recent literature.[8] Only about 55% of the comparable diabetic population is presently screened for DR with the SOC.[12–14] Based on expert opinion (M.H.B) the screening rate of tele-retina was about 80%. The rates of diagnosis of DR in tele-retina and the SOC were obtained from the pilot program.[9] Utilities corresponding to health states were supplemented from the literature.[15]

The Pan-Ontarian cohort was simulated in order to provide a scaled-up estimate of the costs and cost-effectiveness of implementing tele-retina in similar underscreened populations throughout the province. The Pan-Ontarian cohort was based on demographic information derived from the tele-retina pilot program. We assumed specific changes in Ontario's population over 5 years by total income level and mapped the percentage of individuals who were likely to develop diabetes. As there is an association between income quintiles and DR in Ontario, based on that association there is a possible 22 800 individuals with diabetes, assuming a screening rate of 80%, which can be targeted for tele-retina screening.

### Calculations of Model Costs

Data sources for costs: Costs for the pilot and Pan-Ontarian cohort were estimated using the pilot program data whenever possible and/or supplemented from the literature. Table 2 describes estimated costs for tele-retina that was informed by pilot program and published literature. Program costs included (*i*) capital costs; (*ii*) camera transportation costs; (*iii*) labour costs; and (*iv*) consumables costs. We assumed a 5-year equipment lifespan for costs. Table 3 contains summarized OHIP fee codes and their associated rates that were used to estimate the costs for the reference program.

### Economic Analysis

The analysis was conducted from a health care payer perspective (Ministry of Health and long-term care). Only costs associated with running the program were incorporated into the model. We assumed a 1.5% discount rate for both cost and health outcomes as per the Canadian Guidelines for Economic Evaluations.[16] All costs were reported in 2017 Canadian dollars.

**Table 2—Estimated costs for tele-retina pilot program (N = 566)**

| Types of Costs Considered | Cost per Unit |
|---|---|
| Capital Costs (Unit) | |
| One retinal camera with OCT | $65 000 |
| One table lift | $2000 |
| Software maintenance | $4000–5000 |
| One carrying case[8] | $1299.50 |
| Camera Transportation Costs (Unit) | |
| Cab/car | $1135.91 |
| Mileage reimbursed (ophthalmic assistant) | $264.36 |
| Labour Costs | Rate |
| Tele-retina clinical assistant | $15 |
| Grader (ophthalmologist) monochromatic | $45 |
| Grader (ophthalmologist) (30% patients require additional OCT reading) | $25 |
| Consumables | Cost |
| Dilation drops tropicamide 1% | $10 (for 240); cost per unit $0.04 |
| Chin covers/chin cleaners—alcohol wipes | $1.15 cost per pack (200); cost per unit $0.01 |

OCT, optical coherence tomography.

### Cost-Effectiveness Evaluation

The cost-effectiveness of tele-retina was assessed as cost-per case detected (true-positive results) and cost per case correctly diagnosed (true-positive and true-negative results) within the pilot program and Pan-Ontarian cohort.

### Sensitivity Analysis

We conducted a sensitivity analysis of the pilot program and Pan-Ontarian cohort assuming 80% screening rate for tele-retina and 60% screening rate of SOC. These rates were acquired from the published literature assessing the cost-effectiveness of similar programs in comparable populations.[8,17]

## Results

### Base-Case Analysis

As described in Table 4 a total of 566 patients were screened, 444 (78%) individuals who accessed tele-retina were under the age of 65 years, 296 (52%) were female, 556 had type 2 diabetes, and 42 (7%) had no health insurance. The costs included (*i*) capital costs summed up to $22 300; (*ii*) camera transportation costs summed up to $1400.27; (*iii*) labour costs summed to $27 925; and (*iv*) consumables cost summed to $24.7. Total program cost was $51 650, and

**Table 3—Estimated costs for standard screening (reference program)**

| Source (OHIP Fee Code and Consultation with the Expert) | Cost |
|---|---|
| A115 | $52.56 |
| A235 | $85.00 |
| Total per-screening cost | $137.56 |

OHIP, Ontario Health Insurance Plan.

**Table 4—Characteristics of screened patients accessing tele-retina services (N = 566)**

| Variable Category | N (%) |
|---|---|
| Sex | |
| Female | 296 (52.3) |
| Male | 270 (47.7) |
| Age group, years | |
| 20–39 | 41 (7.2) |
| 40–64 | 403 (71.2) |
| ≥65 | 122 (21.6) |
| Diabetes type | |
| Type I | 10 (1.8) |
| Type II | 556 (98.2) |
| Health insurance status for individuals screened for diabetic retinopathy | |
| Noninsured | 42 (7.4) |
| Insured | 524 (92.6) |

per-screening cost was $98.45. After discounting program costs at 1.5%, average per-screening cost of tele-retina over a 5-year period was calculated as $95.77. Per-screening costs for SOC were estimated as $137.56 using OHIP fee codes.

### CEA Tele-Retina Pilot Screening Program

As depicted in Table 5, tele-retina would correctly detect 143 true-positive cases, and SOC would correctly detect 79 cases. Further, tele-retina would correctly diagnose (true-positive and true-negative) 496 cases, whereas SOC would correctly diagnose 247 cases. Tele-retina would correctly detect an additional 64 cases, and correctly diagnose an additional 249 cases, compared with SOC. Total costs of programs for pilot cohort were (*i*) $54 205.82 (tele-retina) and (*ii*) $77 858.96 (SOC). Cost per case correctly detected was (*i*) $379.06 (tele-retina) and (*ii*) $985.56 (SOC). Cost per case correctly diagnosed was (*i*) $109.29 (tele-retina) and (*ii*) $315.22 (SOC). As displayed in Table 6, the ICER was <0, meaning that tele-retina was less costly but more effective than SOC.

### Pan-Ontarian Simulated Cohort

Table 2 describes estimated costs for tele-retina that were informed by the pilot program and summed up using published literature. The costs included (*i*) capital costs summed up to $66 900.45; (*ii*) camera transportation costs summed to $4200.81; (*iii*) labour costs summed up to $1 288 884.00; and (*iv*) consumables cost summed to $1140.00. Total cost of tele-retina for the Pan-Ontarian scenario was $1 294 224.81, whereas per-screening cost was $57.78 when discounted at 1.5% over 5 years. Per-screening costs for SOC were estimated as $137.56.

**Table 5—Base-case scenario (100% screened tele-retina; 55% screened SOC) examination outcomes of tele-retina and SOC screening (N = 566)**

| Measure | Tele-Retina | Standard of Care Retinal Screening |
|---|---|---|
| Number of cases correctly detected | 143 | 79 |
| Number of cases correctly diagnosed | 496 | 247 |
| Total cost of the program | $54 205.82 | $77 858.96 |
| Cost per case correctly detected | $379.06 | $985.56 |
| Cost per case correctly diagnosed | $109.29 | $315.22 |

**Table 7—Base-case scenario (80% screened by tele-retina; 55% screened SOC) examination outcomes of tele-retina and SOC screening Pan-Ontarian cohort (N = 28 500)**

| Measure | Tele-Retina | Standard of Care Retinal Screening |
|---|---|---|
| Number of cases correctly detected | 5848 | 3997 |
| Number of cases correctly diagnosed | 19 995 | 12 480 |
| Total cost of the program (N = 28 500) | $1 643 880 | $3 920 460 |
| Cost per case correctly detected | $281.10 | $982.99 |
| Cost per case correctly diagnosed | $82.21 | $314.14 |

### CEA Tele-Retina Pan-Ontarian Cohort

As depicted in Table 7, tele-retina in the Pan-Ontarian cohort was able to correctly detect (true-positive) 5848 cases, and SOC was able to correctly detect 3997 cases. Further, tele-retina was able to correctly diagnose (true-positive and true-negative cases) 19 995 cases, whereas SOC was able to correctly diagnose 12 480 cases. Considering the Pan-Ontarian cohort, tele-retina would correctly detect an additional 1851 cases, and an additional 7515 cases would be correctly diagnosed, compared with SOC. Total costs of programs for Pan-Ontarian cohort persons were (*i*) $1 643 880 (tele-retina) and (*ii*) $3 920 460 (SOC). Cost per case correctly detected was (*i*) $281.10 (tele-retina) and (*ii*) $982.99 (SOC). Cost per case correctly diagnosed was (*i*) $82.21 (tele-retina) and (*ii*) $314.14 (SOC). As displayed in Table 8, the ICER was <0, meaning that tele-retina was less costly but more effective than standard screening.

### Sensitivity Analyses

The findings of the pilot sensitivity analysis indicated that tele-retina would correctly detect 116 true-positive cases, and SOC would correctly detect 87 cases. Further, tele-retina would correctly diagnose (true-positive and true-negative) 396 cases, whereas SOC would correctly diagnose 311 cases. Tele-retina would correctly detect an additional 29 cases and correctly diagnose an additional 85 cases compared with SOC. Total costs of programs for pilot cohort were

**Table 6—Base-case scenario (100% screened tele-retina; 55% screened SOC) incremental cost-effectiveness results for standard screening versus tele-retina, pilot cohort (N = 566)**

| Screening Strategy | Cost per Patient, $ | Incremental Cost per Patient, $ | Effectiveness | Incremental Effectiveness | ICER, $ |
|---|---|---|---|---|---|
| Cost per case correctly detected | | | | | |
| In-person examination | 137.56 | | 0.165 | | |
| Tele-retina screening | 101.04 | −36.52 | 0.303 | 0.138 | <0 |
| Cost per case correctly diagnosed | | | | | |
| In-person examination | 137.56 | | 0.437 | | |
| Tele-retina screening | 101.04 | −36.52 | 0.712 | 0.275 | <0 |

**Table 8—Base-case scenario (80% screened tele-retina; 55% screened SOC) incremental cost-effectiveness results for standard screening versus tele-retina, Pan-Ontarian cohort (N = 28 500)**

| Screening Strategy | Cost per Patient, $ | Incremental Cost per Patient, $ | Effectiveness | Incremental Effectiveness | ICER, $ |
|---|---|---|---|---|---|
| Cost per case correctly detected | | | | | |
| In-person examination | 137.56 | | 0.140 | | |
| Tele-retina screening | 57.68 | −79.88 | 0.205 | 0.065 | <0 |
| Cost per case correctly diagnosed | | | | | |
| In-person examination | 137.560 | | 0.438 | | |
| Tele-retina screening | 57.68 | −79.88 | 0.701 | 0.263 | <0 |

(*i*) $54 205.82 (tele-retina) and (*ii*) $77 858.96 (SOC). Cost per case correctly detected was (*i*) $467.29 (tele-retina) and (*ii*) $894.93 (SOC). Cost per case correctly diagnosed was (*i*) $136.88 (tele-retina) and (*ii*) $250.35 (SOC). As displayed in Table 9, the ICER was <0, meaning that tele-retina was less costly but more effective than SOC. The findings of the Pan-Ontarian sensitivity analysis indicated that ICER remained <0, indicating that tele-retina dominated SOC.

## Discussion

Findings from our study suggest that tele-retina is a more cost-effective means of screening for DR than the SOC in underscreened Toronto urban and rural communities at risk for developing DR. There is a growing need for more innovative approaches to reach underscreened populations. Approximately 37% of patients enrolled within the Toronto tele-retina screening program have never had an eye examination, and among those who were screened the prevalence of DR was 27%.[9]

The results of this study reinforce the findings of several other studies that focused on at-risk populations. Maberley et al modelled the cost-effectiveness of retinopathy screening by travelling retina specialists versus retinal photography with a portable digital camera in an isolated First Nations cohort with diabetes.[17] Results noted that considering health system perspective the camera program was preferable to the specialist-based program, as being less costly and more effective. In a cost-effectiveness analysis Aoki et al compared tele-retina with SOC screening and follow-up evaluation performed by eye care providers. The strategy was shown to be more cost-effective with US$16 514 per 18.73 QALYs gained versus US$17 590 per 18.58 QALYs gained for non-tele-retina.[18] The cost-savings analysis by Richardson et al, in rural Appalachian health clinic, noted that tele-retina would save $150 per patient over 7 years.[19] Coronado estimated the cost-effectiveness of mobile tele-retina screening compared with in-person examination for diabetic population residing in urban areas of southwestern Ontario.[1] In line with our results, the authors noted that tele-retina is more effective than in-person examination as it would detect and diagnose more cases than in-person examination.

Contrary to our findings, Coronado noted that tele-retina was a costlier strategy than in-person examination. The reason for a possible discrepancy in the results is that they assumed a scenario in which tele-retina would not entirely replace in-person examination, whereas we assumed the programs to run independently of one another.

### Strengths and Limitations

To our knowledge this is the first cost-effectiveness analysis that considered cost per case detected and cost per case correctly diagnosed focused on Toronto's urban diabetic population and rural aboriginal populations at risk for DR. Our initial analysis was based on the Toronto tele-retina program (N = 566), indicating a small sample size, but to understand the large-scale impact of the intervention, we simulated a Pan-Ontarian diabetic cohort. Although a potential limitation, the analysis looked at the single initial visit based on DR screening guidelines for individuals diagnosed with diabetes: type 1 diabetes, rescreen annually; type 2 diabetes, rescreen every 1−2 years. Please note that tele-retina program completes an annual check in with patients to promote compliance with regular screening, increase preventative care and potentially reduce costs to the health system if regular screening is not preformed.

The health care system perspective that we used did not include social benefit payments for patients who had permanent visual disability. Additional sensitivity analyses to explore alternative costs, program sensitivities, specificities, and screening rates of both programs considering a life-time horizon should be explored. Subsequently, future economic evaluations should consider the impact of tele-retina on the prevention of severe vision loss in underscreened urban and rural communities.

**Table 9—Sensitivity analysis (80% screened tele-retina; 60% screened SOC) incremental cost-effectiveness results for standard screening versus tele-retina, Pilot cohort (N = 566)**

| Screening Strategy | Cost per Patient, $ | Incremental Cost per Patient, $ | Effectiveness | Incremental Effectiveness | ICER, $ |
|---|---|---|---|---|---|
| Cost per case correctly detected | | | | | |
| In-person examination | 137.56 | | 0.153 | | |
| Tele-retina screening | 95.77 | −41.79 | 0.204 | 0.051 | <0 |
| Cost per case correctly diagnosed | | | | | |
| In-person examination | 137.560 | | 0.549 | | |
| Tele-retina screening | 95.77 | −41.79 | 0.699 | 0.15 | <0 |

## Conclusions

We conducted an economic analysis of a tele-retina screening program using a health system perspective. Results of this study indicated that tele-retina is a more cost-effective means of screening for DR than the SOC for urban and rural individuals with diabetes at risk for remaining underscreened for diabetic retinopathy.

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