Preventing diabetes blindness: Cost effectiveness of a screening programme using digital non-mydriatic fundus photography for diabetic retinopathy in a primary health care setting in South Africa

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A B S T R A C T

Background: South Africa like many other developing countries is experiencing an epidemiologic transition with a marked increase in the non-communicable disease (NCD) burden. Diabetic retinopathy is the most common cause of incidental blindness in adults. A screening programme using a mobile fundal camera in a primary care setting has been shown to be effective in the country. Information on affordability and cost is essential for policymakers to consider its adoption.

Methods: Economic evaluation is the comparative analysis of competing alternative interventions in terms of costs and consequences. A cost effectiveness analysis was done using actual costs from the primary care screening programme.

Results: A total of 14,541 patients were screened in three primary healthcare facilities in the Western Cape. Photographs were taken by a trained technician with supervision by an ophthalmic nurse. The photographs were then read by a medical officer with ophthalmic experience. A cost effective ratio of $1206 per blindness case averted was obtained. This included costs for screening and treating an individual. The cost just to screen a patient for retinopathy was $22. The costs of screening and treating all incident cases of blindness due to diabetes in South Africa would be 168,000,000 ZAR ($19,310,344) per annum.

Conclusion: Non mydriatic digital fundoscopy is a cost effective measure in the screening and diagnosis of diabetic retinopathy in a primary care setting in South Africa. The major savings in the long term are a result of avoiding government disability grant for people who suffer loss of vision.

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1. Background

The World Health Organisation (WHO) reports that 36 million people die each year due to NCDs and suggest the need to identify cost-effective interventions as urgent and necessary to reduce morbidity and mortality [1]. Worldwide 285 million people are affected by diabetes with 4 out of 5 adults with the disease living in developing countries. Previously thought to have a low prevalence in sub-Saharan Africa, it is projected that between the years 2011 and 2030 there will be a 90% increase in prevalence [2].

In 2003 diabetes prevalence was estimated to be 5–10% in South Africa [3]. However, a recent modelling study shows the prevalence of diabetes to be estimated at 9.7% in people aged thirty and older confirming a growing burden of disease. This represents approximately 2 million cases of diabetes and 16,000 new cases of blindness annually. In South Africa the Years Lost due to Disability (YLD) from diabetes is 169,000 with retinopathy being responsible for 11% [4]. Intensive efforts are required to improve the burden by screening for diabetic sequelae with appropriate interventions [3,5].

Globally, eye disease secondary to diabetes is a leading cause of visual impairment as a result of cataracts or retinopathy [6]. Diabetic retinopathy which, remains asymptomatic until it reaches advanced stages, is the most common cause of incident blindness in diabetic adults aged 20–70 years [7] and is the third leading cause of blindness in South Africa [8]. Retinopathy is preventable and treatable if detected early [6]. Clinical trials have shown that good glycaemic control of diabetes can greatly reduce the risk for retinopathy. There is also evidence that treatment of established retinopathy can reduce the risk of visual loss by 90%. Costs associated with blindness from retinopathy are profound; making screening programmes the mainstay of prevention of blindness due to diabetic retinopathy. Direct health-care costs of diabetes range from 2.5% to 15% of annual health budgets, depending on the prevalence of diabetes and the services available. The costs of lost production to the individual can be as much as five times that of direct health-care costs [9].

Digital non-mydriatic fundus photography is a well established non invasive screening method for the detection of diabetic retinopathy [10–14]. Sensitivity ranges from 78 to 85% in different studies, with specificity rates of between 86 and 100% [15]. A recent systematic review highlighted that there is minimal information on the cost-effectiveness of this screening method and suggested further research on the topic [16].

Current South African guidelines indicate that all people with diabetes should be screened for retinopathy at diagnosis and annually thereafter. Screening is usually carried out by direct or indirect fundal examination, but ophthalmic referral, and treatment, in the form of laser therapy or intraocular injections are only available at tertiary level [6]. Studies show that 55% of people with diabetes will likely suffer from retinopathy but screening at primary care level where the majority receives their care is rare [17]. In an audit of community health facilities in the public sector in Cape Town, there were no documented examinations for retinopathy amongst diabetic patients despite 32% of patients complaining of eyesight difficulties. It is estimated that just 11% have their eyes routinely examined at any level of care [18].

Given these unacceptable rates of routine examinations conducted for diabetic patients, a new service for retinal screening was introduced within the Cape Town metropolitan district health services in 2007 [17]. The service involved the use of a non-mydriatic mobile fundus camera to screen for diabetic retinopathy, which improved the quality of care for patients with diabetes at the primary care level in the public sector [17]. The programme was conducted in the public sector which is government funded in South Africa. Data was collected on costs, both capital and recurrent for this pilot programme. This article provides a cost-effectiveness analysis of this screening programme.

2. Methodology

2.1. Population and setting

The Metropolitan District Health Services (MDHS) in Cape Town provide primary care for a poor working class population through a well-developed network of 45 community health centres [18]. Patients with type 2 diabetes underwent ophthalmologic screening in this study. Patients in the initial pilot phase of this study in 2007 (n = 400) were seen at three community health centres in Cape Town: Khayelitsha, Elsies River and Retreat. The project was then halted in 2008 to assess its usefulness [17] and later extended. In 2009, a further 6973 patients were screened and during the final phase in 2010 a further 7168 patients. Starting in 2007 and ending in 2010 the total number of patients screened was 14,541. This was the data used for the cost effective analysis. Patients seen in all of these health centres are uninsured and come from low socio-economic backgrounds.

2.2. Screening programme

The main steps of the programme are outlined in Fig. 1.

Patients were attendees at a diabetic special care “club” in their respective community health centres, which were run by a professional nurse with support from a doctor. Visual acuity was performed by a community health worker trained by an ophthalmic nurse. Photographs were taken by a trained technician with supervision by an ophthalmic nurse. The photographs were then read by a medical officer with ophthalmic experience [17].

2.3. Study design

The programme evaluated made use of a mobile non-mydriatic digital camera for the purpose of screening patients with diabetes for retinopathy. The camera was transported in a vehicle amongst the three clinics on different days. Over the time period, 1456 patients were referred for ophthalmic consultation, 946 laser operations were performed and 3686 patients had cataract operations (Fig. 2). Patients who had cataract surgery were not screened for retinopathy.
2.4. Economic analysis

A cost-effectiveness analysis was done using secondary data analysis on actual costs and patient numbers seen during the screening programme over three years in the three clinics mentioned above. The analysis was conducted from the perspective of the provincial government as the third party health funder. Direct costs, such as medical and surgical treatment associated with blindness, staff, etc. were included. Transport costs to the patient which were directly related to programme participation, was also included. We did not include time costs of patients or any treatment costs as the programme was run as a free service in the public sector. Indirect costs, such as the use of visual aids, occupational therapy, etc. were excluded from the analysis as South Africa does not embark on providing these facilities to blind patients particularly at primary care level.

Using a comparator was not possible since a consistent screening programme for diabetic retinopathy was not present in these clinics prior to the introduction of the 2007 pilot. Hence, the comparator is defined as current practice in primary care clinics, where people with diabetes are not normally screened for retinopathy [18].

Costs related to diagnosing and treating cataracts had to be included in the costing analysis as these were part of the startup costs incurred during the pilot programme. Thus the costs of cataracts could not be ignored.

The outcome measure was cost per blindness case averted. This cost-effectiveness ratio was calculated by dividing overall programme costs by the number of operations performed to prevent blindness as defined by laser therapy.

Components included in the costing were identified from the screening protocol, and valued based on real costs incurred by the programme. Where real costs had not been recorded, or were not considered as part of the intervention cost (such as staff salary) costs were taken from actual salaries paid by the government.

Operating room costs, patient transport fees and clinic overhead costs were obtained from journal articles of other cost-effectiveness analyses done in South Africa. Salaries were based on current amounts paid by public sector facilities. Time spent participating in the screening programme was calculated for all staff. This time was then divided by the annual salary to work out the actual staff cost component. Other recurrent costs were calculated on an annual basis. Equipment costs were based on quotes obtained in February 2011 from GENOP holdings, who manufacture the camera and laser used in the screening programme. Patient numbers were obtained from each of the 3 clinics.

Costs were separated into capital and recurrent costs for the programme. These costs were captured on an excel spreadsheet. For capital costs ‘years of useful life’ (equipment) was also included in the analysis. Annual economic costs were calculated by dividing replacement value by the years of useful life. No discounting was used in the analysis due to the short time frame.

Uncertainty analysis was performed to generate uncertainty around the cost-effectiveness ratio. As this analysis was
based on the actual numbers of patients seen in the programme, no uncertainty was used around the outcome measure of patients seen.

The analysis was performed using Ersatz version 1.2 software (www.epigear.com) was used in conjunction with Microsoft Excel 2010. A Bayesian approach with fixed upper and lower limits of 20% with 1000 iterations was used. The following variables were simultaneously evaluated: camera, laser equipment, software and laptop computer related to all equipment, microscope including lens, phaco machine and hand pieces, motor vehicle, patients travel costs, clinic overhead costs and machine and vehicle maintenance costs. In summary, all costs were evaluated with the exclusion of salaries as these were based on the actual salaries currently paid by the public sector.

3. Results

The total costs for screening and treating all patients in this programme was 9,937,412 ZAR ($1,142,231) (CI: 8,696,997–11,274,297). See Table 1. A full table with further detail is available as an Appendix.

A total of 4632 cases of patients with diabetes were treated for retinopathy and cataract (Fig. 2). Laser therapy for retinopathy was then provided for 946 patients. The cost for retinopathy screening alone was 189 ZAR ($22) per person with diabetes. The incremental cost-effectiveness ratio (ICER) for retinopathy was 10,500 ZAR ($1206) (9190–12,034) per blindness case averted. The cost for laser treatment in retinopathy confirmed cases was 1249 ZAR ($144) per person. The treatment of cataracts (surgery + post surgery eye drops) accounted for 5,882,856 ZAR ($676,190). The cost just for cataract management amounts to 1956 ZAR ($183).

It is estimated that there are 16,000 incident cases of blindness due to diabetes each year in South Africa [4]. Based on these results, the costs of preventing these cases i.e. screening and treating them would be 168,000,000 ZAR ($19,310,344) per annum. If all cases of blindness due to diabetic retinopathy were identified and treated, the programme would avert 18,590 YLD. Fig. 3 shows the uncertainty around the cost-effectiveness result. Each dot on the scatter plot represents 1 iteration of the uncertainty analysis.

Effectively there is a 98% chance of the ICER falling below the Willingness to Pay (WTP) line. The WTP line was set at 1100 ZAR. The annual disability grant in South Africa is 12,120 ZAR ($1393).

Sensitivity analysis was performed using Ersatz software. The most significant costs were the purchasing costs of the microscope and the phaco machine. As we do not have extensive epidemiological data on the patients screened, we may have overestimated the number of blindness cases averted due to laser therapy as some cases may not have lead to blindness. This may be as high as 50% of proliferative diabetic retinopathy cases [19]. A sensitivity analysis indicates that if overtreatment of this level occurred, the cost-effectiveness ratio would be 23,327 ZAR ($2681)/blindness case averted.

4. Discussion

The results demonstrate that digital non-mydriatic fundus photography is not only an effective screening and diagnostic tool for diabetic retinopathy but that it is also cost-effective in the South African primary care setting where the majority of people with diabetes receive their care. A study in Ontario, Canada reporting cost-effectiveness showed a value of $3900 per sight year was saved [16]. Hence, the value of USD $1206 in South Africa to avert one case of blindness is relatively low. Even with 65% coverage of diabetic patients (if just 65% of people with diabetes agree to screening and attend clinic), this study confirmed that the camera screening programme is still cost-effective [16]. Other studies conducted in the US using the non-mydriatic digital funduscopy programme coupled with telemedicine were also shown to be cost effective [20,21].

The sensitivity and specificity of photographic images of the retina being taken by a technician and read by an ophthalmologist has been well established [10–14]. In SA, it may not be possible to have an ophthalmologist read all photographs as was the case in this programme (mentioned above). In order to compensate for this we look to the example of the incorporation of family physicians in Spain who read the images from digital non-mydriatic fundus photography. In this case the sensitivity was over 90% in all parameters: diabetic retinopathy (95.2%), diabetic macular oedema (92.3%) and macular lesions (96.0%). Also positive predictive values were high in all parameters, 85.9% for diabetic retinopathy, 91.0% for macular lesions and 90.7% for diabetic macular

![Cost effectiveness scatter plot](image-url)
Table A1—Detailed cost components in ZAR.

<table>
<thead>
<tr>
<th>Type of cost</th>
<th>Replacement value</th>
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<th>Upper limit</th>
<th>Years of useful life</th>
<th>Annual economic cost</th>
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<tr>
<td>Equipment</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>1,35,200</td>
<td>2,02,800</td>
<td>10</td>
<td>5,35,636</td>
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<td>Flash drives</td>
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<td>159.2</td>
<td>238.8</td>
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<td>190</td>
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<td>1000</td>
<td>800</td>
<td>1200</td>
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<td>200</td>
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<tr>
<td>Mikrokeratome nidek</td>
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<td>3,60,000</td>
<td>5,40,000</td>
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<td>45,000</td>
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<td>2000000</td>
<td>3000000</td>
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<td>25,000</td>
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<tr>
<td>Operating microscope</td>
<td>4,00,000</td>
<td>11,20,000</td>
<td>16,80,000</td>
<td>10</td>
<td>1,40,000</td>
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<td>Operating sets</td>
<td>29916</td>
<td>23932.8</td>
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<td>Phaco machine</td>
<td>7,50,000</td>
<td>6,00,000</td>
<td>9,00,000</td>
<td>10</td>
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<td>31,200</td>
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<td>8400</td>
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<td>1400</td>
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<td>Laser scan</td>
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<td>6,80,000</td>
<td>10,20,000</td>
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<td>1,70,000</td>
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<td>4800</td>
<td>7200</td>
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<td>Lens</td>
<td>12,000</td>
<td>9600</td>
<td>14,400</td>
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<td>12,000</td>
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<td>Polo vivo 1.4 hatch used</td>
<td>1,26,490</td>
<td>1,01,192</td>
<td>1,51,788</td>
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<td>25,298</td>
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<td>Recurrent costs</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff salaries</td>
<td>Annual*</td>
<td>Daily**</td>
<td>Number of days/month required for programme*</td>
<td></td>
<td></td>
</tr>
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<td>Doctor with ophthalmic background</td>
<td>7,22,871</td>
<td>2780</td>
<td>4</td>
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<td>4,94,852</td>
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<tr>
<td>Technician</td>
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<td>419</td>
<td>1</td>
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<td>Auxiliary nurse</td>
<td>1,14,759</td>
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<td>Staff nurse</td>
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<td>Community health worker</td>
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<td>Total materials, maintenance and travel expenses</td>
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<td></td>
<td></td>
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<td>Materials and drug supplies</td>
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<tr>
<td>Steroid/antibiotic eye drops</td>
<td>13</td>
<td>10.4</td>
<td>15.6</td>
<td>1 month</td>
<td>14,136</td>
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<tr>
<td>(after cataract surgery)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>156</td>
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<tr>
<td>Ketorolac drops (after cataract surgery)</td>
<td>60</td>
<td>48</td>
<td>72</td>
<td>1 month</td>
<td>720</td>
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<td>1105</td>
<td>884</td>
<td>1326</td>
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<td>Operation and maintenance</td>
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<td>Telephone, electricity and water</td>
<td>160</td>
<td>128</td>
<td>192</td>
<td>per day</td>
<td>1920</td>
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<td>Operating theatre running costs</td>
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<td>19.2</td>
<td>28.8</td>
<td>per min</td>
<td>720 per cataract op</td>
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<td>611.2</td>
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<td>3984</td>
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<tr>
<td>Equipment maintenance (camera)</td>
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<td>2000</td>
<td>3000</td>
<td>1</td>
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<tr>
<td>Phaco Service/year (for cataract surgery)</td>
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<td>8000</td>
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<td>10,000</td>
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<td>Travel costs for referral patients</td>
<td>35</td>
<td>28</td>
<td>42</td>
<td>per visit</td>
<td>420</td>
</tr>
</tbody>
</table>

* These costs were multiplied by 12 for the annual cost estimation.
** These subheadings refer only to the staff costs section.

oedema. Specificity was very high, with values over 99% in all parameters [6]. This demonstrates that even if non-ophthalmologists read the photographs, diabetic retinopathy can be accurately diagnosed [22].

In South Africa, interventions for visual assistance are almost absent from service delivery. Aside from a few private organisations offering Braille classes and others which assist with the provision of guide dogs, visual aids are largely unsupported. Government support is in the form of a disability grant for blind people. This is provided monthly usually for a combination of medical problems (which may include blindness) for the rest of the individual’s life. The disability grant is 1010 ZAR ($116) per month with an annual cost of 12,120 ZAR ($1393) [23]. The cost of screening and treating blindness for people with diabetes (either through retinopathy or cataracts) is equivalent to less than one year of the disability grant.

Retinal screening programmes have the potential to result in additional gains. Firstly, prevention of blindness can lead to extension of working years for the employed. Secondly, integration of screening with a routine primary care clinic visit would reduce patients’ inconvenience, time taken off...
work and transport costs. Most importantly, no real monetary value can be given to preserving sight. Screening and treating retinopathy would reduce morbidity related to diabetes and sighted individuals can retain their independence.

Screening for retinopathy is a current gap in diabetes care at a primary care level in many settings and our results show that it is a cost-effective method to reduce diabetes related blindness. Several developed countries have screening programmes for diabetic retinopathy and low and middle income countries are working with WHO to develop tailored programmes [9]. Whilst our study was performed in a, low socio-economic urban setting, rural communities could benefit as well. For example, rural diabetic communities in France and New Zealand have benefitted [12,13]. This has potential in sub-Saharan African countries where transport systems are not as well developed and rural communities are difficult to access.

Health care reform has now begun in South Africa. Primary healthcare re-engineering is a key component of national strategic plans and priorities, with a greater emphasis on health promotion and prevention. In this regard, the screening programme for retinopathy using digital non-mydriatic fundus photography could be a tangible improvement at the primary care level for people with diabetes at the primary health care level [24].

Increased human resources will be required to run the programme. Furthermore, training is essential for staff and should be intensified [17]. Interestingly the analysis showed that staff salaries were not the highest cost driver in the programme; this cost was attributable to equipment required to screen for diabetic retinopathy.

4.1 Limitations

As far as possible costs were based on information available in South Africa, but some costs were not available and had to be obtained from studies conducted elsewhere e.g. overhead costs. Whilst it is true generalisability may be compromised as Cape Town is different from other parts of South Africa (with regards to disease prevalence and the stage at which patients present to health care facilities), the patients in this programme were from low socio-economic backgrounds that are representative of urban communities in SA. Initially costs will increase in areas that have significantly high prevalence of diabetes, but so will savings in the long term. A further limitation is that no data is available on the number of actual patients that were seen at tertiary level (having being referred through primary healthcare services) for retinopathy and or blindness that were not referred by this screening service. Thus, some patients did not become blind from their diabetic retinopathy. As a result we may have overestimated the health impact because some patients may be seen for treatment or annual screening at tertiary level (albeit at a higher cost).

5 Conclusion

We have shown that preventing blindness in people with diabetes using digital non-mydriatic fundus photography is not only effective but is cost-effective in South Africa. This evidence of a “best buy” in an urban primary care setting suggests that it could be scaled up, extended to other provinces as well as to other countries in the region. In the future, with newer cameras and software, it is likely that this affordable intervention may become even less costly. Other models of providing service in smaller towns and remote areas could also be explored and would likely save patients and their family’s time and money for long and repeated trips. In summary, an intervention of this nature could be pivotal for growing numbers of patients with diabetes around the world. It also demonstrates the growing need for evidence regarding affordability and costs as SA heads towards universal health care.

Conflict of interest

The authors declare that they have no conflict of interest.

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Author contributions

All authors contributed to the drafting and editing of this manuscript. TK and MB were responsible for data and statistical analysis. KH and NL conceived the study.

Appendix A

See Table A1.

References


