Screening Uptake in a Well-Established Diabetic Retinopathy Screening Program

The role of geographical access and deprivation

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OBJECTIVE — To identify criteria that affect uptake of diabetes retinal screening in a community screening program using mobile retinal digital photography units.

RESEARCH DESIGN AND METHODS — Data from the regional diabetes population-based retinal screening program and regional ophthalmology laser database were linked to patient postal code (zip code) data. We used distance from retinal screening event, social deprivation scores, and demographic information to identify risk factors for nonattendance at a diabetes retinal screening event. Patients were subdivided into urban (>125,000 population), other urban (3,000–125,000 population), or rural (<3,000 population) depending on where they lived. Data were collected from 2004 to 2006 inclusive and included 15,150 patients and 32,621 eye screening records.

RESULTS — The mean ± SD age of patients was 63 ± 15 years, and 54% were male. Mean travel time to retinal screening event varied from 7.1 to 17.0 min. For 12% of missed appointments, patients were more likely to be younger, to have longer diabetes duration, to have poor A1C and blood pressure control, to be smokers, and to live in deprived areas. Poor attendance was not associated with sex or distance to retinal screening event.

CONCLUSIONS — Social deprivation is strongly associated with poor attendance at retinal screening events. Time traveled to screening event was not associated with attendance in this study of a mobile retinal screening service, which visited general practitioner surgeries. This data can help inform population-based diabetes retinal screening programs about improving patient uptake.

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Blindness is one of the most feared complications of diabetes (1). Across the U.K., annual digital retinal photography has been introduced as a screening program because it has been shown to be a cost-effective way of reducing visual impairment (2–5). The clinical effectiveness of the program depends on the sensitivity and specificity of the tools being used and upon the population coverage. Digital retinal photography has consistently been shown to be 80% sensitive and 90% specific at detecting sight-threatening lesions (6–8). Population coverage is at least as important but receives less research attention. In screening programs using ophthalmoscopy and retinal photography (9) or optometry (10), blindness due to diabetes was found mainly in patients who did not attend screening or ophthalmology clinics. Improving screening sensitivity beyond 80% will result in small benefits in terms of lowering visual impairment. This is in contrast to improving population coverage. The last members of the diabetes population to be reached by screening are likely to be those who will benefit most, and reaching such individuals is expected to have a major impact on visual impairment and be cost-effective (11).

Screening for diabetic retinopathy is unlike most screening programs. Screening for cervical, breast, or colorectal cancer involves screening a healthy population within a defined age category. Screening for diabetic retinopathy involves screening in a population with a predefined illness who will thus have many other health demands placed on them. Also, once started, screening for diabetic retinopathy will continue for life. For these reasons, the uptake of screening may well be different for diabetic retinopathy compared with other programs. Little is known about the population characteristics that determine uptake of screening in diabetic retinopathy, although it has been suggested that screening uptake may be less in rural than urban areas (12), and it is possible that poor uptake in rural areas may reflect issues of accessibility to the eye screening centers.

We aimed to examine the population characteristics that determine screening uptake in a well-established diabetic retinopathy screening program (13) that uses both mobile camera units and static camera units manned by trained retinal screeners. Controlling for individual factors expected to influence screening uptake, we aimed to test whether *1*) those living in deprived areas were less likely to respond positively to the invitation to attend eye screening, *2*) those living further from the site of their designated visit were less likely to respond positively to the invitation to attend eye screening, and *3*) there were significant practice-level variations in screening uptake.

RESEARCH DESIGN AND METHODS

All patients with diabetes in Tayside, Scotland ($n = 16,258$, representing 4.2% of the total population of 387,095) undergo annual digital retinal photography as part of a national screening program. The screening program uses two mobile retinal cameras that travel around each general practice location in rotation and one static camera in a central

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Table 1—*Summary statistics for explanatory variables*

	All patients			Patients invited to eye vans		
Variable	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Sex						
Male	0.54	0	1	0.56	0	1
Female	0.46	0	1	0.44	0	1
Age (years)	62.77	12	102	63.42	12	101
A1C						
Excellent <7%	0.38	0	1	0.40	0	1
Good 7–8%	0.29	0	1	0.29	0	1
Unsatisfactory 8–9%	0.17	0	1	0.16	0	1
Poor >9%	0.16	0	1	0.15	0	1
Duration of diabetes (years)	7.34	0	74	7.21	0	74
Blood pressure (mean arterial pressure)	97.32	56	154.67	97.73	56.66	153.33
Smoking status						
Nonsmoker	0.40	0	1	0.40	0	1
Ex-smoker	0.40	0	1	0.42	0	1
Smoker	0.20	0	1	0.18	0	1
Accessibility to service (min)	11.71	0	87.16	5.24	0	87.16
Carstairs deprivation						
1 Least deprived	0.17	0	1	0.18	0	1
2	0.16	0	1	0.21	0	1
3	0.19	0	1	0.22	0	1
4	0.23	0	1	0.24	0	1
5 Most deprived	0.25	0	1	0.15	0	1
Screening location						
Ninewells Hospital	0.47	0	1			
Eye van	0.52	0	1			
Urban rural classification						
Dundee	0.41	0	1			
Other urban	0.37	0	1	0.65	0	1
Rural	0.22	0	1	0.35	0	1

site within Dundee. Tayside covers an area of 3,000 square miles, with 69 general practices. All images and grading results were stored on a local software program called Eyestore.

Data were collected from the regional eye screening database (Eyestore), the regional diabetes electronic record (SCI-DC [Scottish Care Information–Diabetes Collaboration]), patient cohort data from the community health index register, and the regional ophthalmology laser database (Table 1). The eye screening data include date of eye screening, camera location, attendance status, and screening results. SCI-DC provides data on date of diagnosis of diabetes, year of birth, and clinical tests such as A1C, blood pressure, and smoking status. The patient cohort data include records on sex, date of address change, year of birth, practice registered, and date of leaving Tayside. The ophthalmology laser data provides date of laser treatment for patients with diabetic retinopathy. All databases contain a pseudopatient identifier so they can be linked together anonymously. The study was approved by the Tayside Caldicott Guardian, as recommended by the Tayside Committee on Medical Research Ethics.

Patients were assigned anonymously to census-based geographical areas based on their residential postal code. To control for disclosure risks, geographical data were attached to the postal codes using a third party (the Health Informatics Centre, Dundee) and the postal codes were removed from the final research dataset. The geographical data include accessibility measures derived using geographical information systems indicating the distance from each person's residential postal code to their allocated site for screening. This was calculated as the shortest estimated travel time along road networks in minutes. Different road types in urban and rural areas were allocated different average speeds in this calculation. Carstairs (14) deprivation scores were also attached to the residential postal codes; this score is a widely recognized geographical measure of material deprivation that was specially created for the Scottish context. The index is a composite score based on four variables: the percentage of unemployed male residents over age 16 years, the percentage of individuals in households with one or more people per room, the percentage of residents in households with no car, and the percentage of residents in households with an economically active head of household in social class IV or V. Social class is categorized according to occupation as follows: class I, professionals; class II, managerial/technical workers; class III, skilled workers; class IV, partially skilled; and class V, unskilled. These variables are then standardized and summed for each output area. For descriptive purposes, an urban/rural identifier was also attached to the residential postal codes, distinguishing Dundee and other urban (settlements with a population between 3,000 and 125,000) and rural areas in Tayside, based on the Scottish Household Survey sixfold urban/rural classification for Scotland (15).

Nonattending diabetic patients were those invited for screening but who failed to attend. Patients who cancelled their eye screening appointment for a variety of possible reasons were excluded from the analysis. We also confined the analysis to patients invited to the static unit at Ninewells Hospital, Dundee, and the two mobile eye vans. Therefore, patients who attended the eye clinic, research clinic, and "other" clinics, such as antenatal clinics, were removed from the database. The period of data collection for the hospital and the first eye van was January 2004 to December 2006. For the second eye van, which was introduced later, the period covered May 2004 to December 2006. The eye screening data includes 15,150 patients, some of whom were invited more than once during the period, giving a total of 32,621 records.

Statistical analysis

We have panel data with repeated observations for the same patient, and our outcome measure is a binary variable distinguishing those who did or did not attend. Random-effects logit models were used to model the propensity of missing the eye screening. These longitudinal models account for both within- and between-individual variation. We also

Table 2—*Mean travel time and proportion of patients missing invitation by urban/rural types*

Urban rural classification	Mean travel time	Proportion not attending
Dundee	17.0	10.7
Other urban	7.1	14.7
Rural	9.5	12.6

tested whether there was significant practice variation using a multilevel model.

RESULTS — The mean ± SD age of patients was 63 ± 15 years, and there were more male than female subjects in the dataset (54 vs. 46%). Between 2004 and 2006, 36% of patients were invited once and 64% twice or more. Overall, 12% of the invitations to attend eye screening were missed, with the highest proportion of nonattendees being in urban areas other than Dundee (Table 2), even though patients in these areas had the shortest travel times to the invited screening location.

Model 1 examines the propensity of failing to attend eye screening for all patients, regardless of whether their screening location was static (Ninewells Hospital) or one of the two mobile eye vans (Table 3). Age is significant, with young people having a higher propensity to miss the eye screening, while sex makes no difference. Patients with a longer history of diabetes had a higher risk of missing the screening, as did those who recorded poor A1C before the screening, those with higher blood pressure, and those who smoked or were ex-smokers.

The average distance traveled by patients to their retinal screening event was 3.3 miles. Geographical accessibility appears to have no effect on attendance, but patients who resided in the most deprived and the second most deprived areas were 2.32 (95% CI 1.92–2.81) and 1.5 (1.24–1.82) times as likely than those in the least deprived areas to miss the screening. Patients who were invited to eye vans for screening were nearly three times (odds ratio 2.92 [95% CI 2.48–3.44]) as likely to miss the screening as patients invited to the static unit at Ninewells Hospital. Model 2, therefore, examines only those invited to the eye van for screening (Table 3).

Overall, the results appear to be similar to the modeling results for all patients who were invited to both the Ninewells Hospital and eye vans (Model 1). The deprivation effect remained strong, though; patients in the most deprived areas were 1.98 (95% CI 1.57–2.5) times less likely to attend than those in the least deprived areas. To identify whether there are practice variations in patient uptake, a multilevel model was used. Controlling for demographic and social factors and medical conditions, as in models 1 and 2, no significant practice-level effects were found (model not shown). Only 45 cases of laser incidents were carried out between 2004 and 2006 in the screened population. A logit model showed that those patients who missed eye screening at least once during the period were 3.13 (1.58–6.18) times as likely to receive subsequent laser treatment.

CONCLUSIONS — Our study identified a number of patient features that are associated with poor attendance at a diabetes retinal screening program. These included young age, poor glycemic and blood pressure control, smoking, and long duration of diabetes. This is unfortunate, as poor glycemic control, poor blood pressure control, and long duration of diabetes are probably the three strongest risk factors for the development of diabetic retinal disease (16,17). Thus, those patients who are least likely to attend screening are also those at greatest risk of sight-threatening eye disease. Our study included a wide range of ages and, in particular, a significant number of people aged <50 years, who may be more confident about their health, even though in this context such confidence may be misplaced.

While ease of access to screening units is associated with uptake in other studies (18,19), it was notable that the travel distance between the patients' residences and the site of screening did not affect the likelihood of attendance in our analysis. This suggests that, overall, the mobile retinal cameras provide sufficient accessibility to patients, and further attempts to improve access by including more stopping points may not be useful. The policy of a mobile unit attending

Table 3—*Odds ratio (95% CI) of failure to attend eye screening for all patients invited to both the mobile units and the static, hospital-based unit (model 1) and for only those patients invited to the mobile units (model 2)*

Variable and category	Model 1	Model 2
Sex		
Male	1	1
Female	0.997 (0.892–1.114)	1.040 (0.909–1.190)
Age	0.968 (0.965–0.972)*	0.964 (0.959–0.969)*
Duration of diabetes		
Years	1.019 (1.012–1.027)*	1.024 (1.015–1.033)*
A1C		
Excellent	1	1
Good	0.931 (0.819–1.057)	0.942 (0.806–1.100)
Unsatisfactory	0.937 (0.805–1.090)	0.981 (0.815–1.180)
Poor	1.253 (1.079–1.455)*	1.426 (1.190–1.709)*
Blood pressure (mean blood pressure)	1.012 (1.007–1.018)*	1.007 (1.001–1.014)†
Smoking status		
Nonsmoker	1	1
Ex-smoker	1.144 (1.008–1.299)†	1.134 (0.975–1.320)
Smoker	2.516 (2.186–2.895)*	2.265 (1.904–2.694)*
Accessibility to service (min)	0.996 (0.988–1.003)	1.014 (0.999–1.029)
Carstairs deprivation		
1 Least deprived	1	1
2	1.061 (0.864–1.303)	1.000 (0.799–1.253)
3	1.176 (0.964–1.433)	1.071 (0.859–1.335)
4	1.500 (1.239–1.816)*	1.414 (1.140–1.753)*
5 Most deprived	2.321 (1.917–2.811)*	1.981 (1.573–2.495)*
Screening location		
Ninewells Hospital	1	
Eye van	2.923 (2.484–3.441)*	
Constant	0.016 (0.013–0.021)*	0.061 (0.047–0.078)*
Observations (patients)	25,908 (11,384)	13,574 (6,465)

*1% significance level; †5% significance level.

mainly general practitioner practice premises across Tayside appears to be sufficient to reach most patients. Indeed, based on a cost-effectiveness analysis, it may even be possible to reduce the number of peripheral sites visited by the mobile retinal screening unit.

On the other hand, social deprivation had a strong inverse association with screening uptake, with those in more deprived areas being considerably less likely to attend. This suggests that a targeted approach of increasing the number of screening opportunities in areas of high social deprivation could be helpful. We found no evidence of practice-level variations in uptake, even though enthusiasm from the general practitioner is clearly associated with patient attendance at screening in other screening programs (20). Of course, improving uptake in more socially deprived areas would require engagement with a general practice.

Other screening programs have attempted to improve participant uptake using a number of different means. Personalized invitations (18) with an explanatory brochure have been shown to be helpful (21), especially if endorsed by the general practitioner (22). Reminder letters and telephone calls also help (18,19). Visiting a patient's home can encourage attendance (23) but is labor intensive and may not be cost-effective. It has been suggested that any intervention, whatever its nature, may be useful (24), and several interventions may be no better than just one. Drug addiction programs have used financial incentives, such as food vouchers and rent payments (25), but these would be more controversial in a diabetes retinal screening program.

Many of the examples illustrated above come from experience in breast and cervical screening programs, which involve otherwise "healthy" patients. Diabetic retinopathy screening programs engage with patients who have a chronic condition (i.e., diabetes). Such patients have regular contact with health care services, and their attitude toward efforts to improve uptake may be significantly different from those of otherwise healthy patients. We thus need to be careful about extrapolating the data from breast and cervical screening to diabetic retinal screening.

One intriguing finding was that uptake was considerably better among patients in Dundee who use the static facility at Ninewells Hospital than among those elsewhere in Tayside who rely on the mobile eye vans. This is despite the fact that travel times were higher in Dundee and social deprivation is certainly worse than elsewhere in Tayside. One simple explanation for this is that patients' appointments for eye screening were linked to hospital attendance for other diabetes-related clinics. Unlike patients attending the mobile eye vans, many of the patients attending Ninewells may not have needed to make a special trip. Hence, we modeled the attendance for all patients and those attending the mobile clinics separately (Table 3).

Finally, we also found that patients with diabetes who were less likely to attend for retinal screening were more likely to attend for laser photocoagulation. Patients who were already attending the ophthalmology clinic were excluded from this analysis, and so it only included those patients who were deemed suitable for screening and did not have previously known sight-threatening retinopathy. This again suggests that those patients who are not being reached by screening are those in greatest need of ophthalmological intervention. Of course, since many patients not attending screening ended up receiving laser treatment, it is possible that such patients bypassed the screening process and still received appropriate care. However, it is more likely that such patients attended the ophthalmology services when they were symptomatic and did not receive laser treatment at the most appropriate time, with likely poorer outcomes of laser photocoagulation. It is also likely that some patients presented so late that laser photocoagulation was no longer possible, resulting in a poor outlook for visual acuity. As Tayside, Scotland, is reasonably representative of Scotland as a whole, it is likely that the results are generalizable within Scotland, where there is a national retinal photography screening program. The results may be less applicable to other areas where health care delivery and social factors may be different. In addition, although we highlight a problem, further research is required to identify what the best solutions may be, although we suggested some possibilities earlier.

In summary, we have identified that social deprivation is strongly related to poor attendance at a diabetes retinal screening program. Interestingly, time traveled to the screening episode was not associated with attendance rates. This mobile diabetes retinal screening program visits individual general practitioner practices and appears to provide sufficient accessibility in general, but further improvement is required in trying to reach patients living in socially deprived areas.

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