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A small number of older type 2 diabetic patients end up visually impaired despite regular photographic screening and laser treatment for diabetic retinopathy

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ABSTRACT

Purpose: The present study describes the prevalence of visual impairment and blindness in a geographically defined population 8 years after the introduction of a screening programme in 1987 for early detection of sight-threatening diabetic retinopathy.

Methods: Of 374 patients with diabetes, comprising 2.6% of the population in the study community, 72% were examined with fundus photography or biomicroscopy during 1994–95. These patients form the basis of this study. The screening programme was fulfilled by 93% of subjects, all of whom underwent ophthalmic examinations at least every other year. A total of 79 eyes in 52 patients received photocoagulation for macular oedema alone or in combination with severe non-proliferative or proliferative retinopathy.

Results: Eight years after the implementation of the programme, only three patients, all with type 2 diabetes (diabetes diagnosed at or after 30 years of age), had visual acuity ≤ 0.1 . The total number of eyes with visual acuity ≤ 0.5 was higher in insulin-treated type 2 diabetic patients ($n = 20$) than in those on oral treatment ($n = 5$) or diet treatment only ($n = 1$) ($p = 0.006$ in both cases). The only independent risk factor for visual impairment in eyes with sight-threatening retinopathy was age.

Conclusion: A small number of older type 2 diabetic patients end up with visual impairment due to unsuccessful photocoagulation of macular oedema.

Key words: population – diabetic retinopathy – blindness – screening – laser coagulation

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Diabetic retinopathy is the principal cause of blindness before the age of 60 years in industrialized countries (Williams 1994). Intensified metabolic control and blood pressure treatment reduces the risk of sight-threatening diabetic retinopathy (Diabetes Control and

Complications Trial Research Group 1993; UK Prospective Diabetes Study Group 1998a,b). However, prevention of visual impairment once sight-threatening retinopathy (proliferative retinopathy and/or macular oedema) has developed requires laser treatment (Diabetic Retino-

pathy Study Research Group 1987; Early Treatment Diabetic Retinopathy Study Research Group 1991). Since photocoagulation can preserve but seldom restore visual function, the best treatment affects are obtained before visual acuity (VA) has been affected. Screening for early detection of treatable diabetic retinopathy is one of the most important tools in the prevention of diabetic blindness (Stefánsson et al. 2000). Such screening procedures are cost-effective and there are several modes of organization and methods that can be used depending on geographical areas and technical facilities available (Stefánsson et al. 2000).

We have previously described low frequencies of visual impairment in both type 1 and type 2 diabetes after the introduction of a screening programme for early detection of sight-threatening retinopathy in combination with laser treatment when appropriate (Agardh et al. 1993). That study was representative of a type 1 but not of a type 2 diabetic population in Sweden, as the screening programme at the time included all type 1 diabetic patients but excluded those with type 2 diabetes in receipt of primary care. The present study was conducted in order to describe the prevalence of visual impairment in a population-based survey of diabetic patients in one Swedish community.

Diabetic patients under routine care in general practice or at the nearest depart-

ment of medicine were offered regular fundus examinations in a screening programme. This study was conducted 8 years after the introduction of the programme. One of the study's principal aims was to establish to what extent patients had undergone fundus examinations. A second aim was to register the examination intervals. A third aim was to describe the prevalence of blindness and visual impairment and to relate the number of visually impaired eyes to treatment of diabetes, degree of metabolic control, hypertension, renal variables, and body mass index (BMI).

Patients and Methods

Patients

The total population of the Burlöv Community in southern Sweden numbered 14 500 inhabitants in 1995. All patients in the community with diabetes mellitus (374) in receipt of primary health care ($n=257$) or in the care of the nearby medical department ($n=117$) during two calendar years 1994–95 were identified. The diabetes diagnosis relied on WHO criteria from 1985 (World Health Organisation 1985). Type 1 diabetes was defined as diabetes diagnosed before 30 years of age, and type 2 diabetes as diabetes diagnosed at or after 30 years of age. Out of 374 patients, 268 (72%) had undergone an eye examination during those 2 years. These patients form the basis of this study.

Demographic data for the community in 1995 are compared with equivalent data for the country of Sweden in Table 1. Age distribution and rate of unemployment were similar but mean annual income was slightly lower, at SEK148 000 compared with a national mean of SEK151 000. The increase in mean annual income over the period extending from 3 years before to 3 years after the period of study (1994–95) was also lower than in national terms. Higher education was slightly less frequent than the national average. The population in the community increased more during the period than it did in Sweden as a whole and the proportion of non-Swedish citizens was higher, at 17% versus 6%.

Programme for ophthalmologic examinations and treatment

A screening programme for early detection of sight-threatening diabetic retino-

pathy was introduced in the community in 1987. This offered diabetic patients regular ophthalmologic examinations by fundus photography (Nikon NFC 50). After dilation of the pupils, three 45° fields per eye were photographed. These comprised one nasal field, one temporal field and one central field that included stereo photos of the macula. Patients with no or mild retinopathy continued in the screening programme and were photographed at 1–2 year intervals after re-referral by the general practitioner. Patients with moderate to severe retinopathy (Early Treatment Diabetic Retinopathy Study Research Group 1991) were examined by biomicroscopy more frequently outside the screening programme by experienced ophthalmologists and, when appropriate, treated with photocoagulation.

Laser treatment

Laser coagulation was offered within 3 months of diagnosis. Patients with clinically significant macular oedema received focal and/or grid treatment and patients with severe non-proliferative retinopathy or proliferative retinopathy received pan-retinal photocoagulation according to guidelines from the Early Treatment Diabetic Retinopathy Study Research Group 1991. Treatment of the macular region preceded that of the periphery.

Visual acuity

Visual acuity was tested using fixed-dis-

tance charts. Three levels were identified according to VA in the better eye, as ≤ 0.1 , 0.2–0.4, and ≥ 0.5 . Blindness was defined as VA ≤ 0.1 and visual impairment as VA 0.2–0.4.

Medical variables

Medical variables registered were HbA_{1c} and blood pressure levels, antihypertensive medication, urinary albumin and serum creatinine levels and BMI.

Analytical techniques

Glycosylated haemoglobin levels were analysed by ion exchange chromatography using microcolumns (Bio-RAD, Richmond, California, USA) (reference range: 4.0–5.6%). Urinary albumin concentration was measured with an electroimmunoassay using human albumin (Kabi Vitrum, Stockholm, Sweden) (detection limit 12.5 mg/L) or by turbidimetry with an automated analyser (COBAS Mira, Roche, Switzerland), antibodies (rabbit antihuman albumin) and techniques as described by Dakopatts (Copenhagen, Denmark) (detection limit 5 mg/L). Creatinine levels were measured with an enzymatic method (creatinine-hydrolase; Ektachem-analyzer, Instrument Kodak, New York, USA).

Statistics

Student's unpaired two-tailed *t*-test was used for equal and Mann-Whitney's test for unequal standard deviations. Pearson's and Spearman's correlation tests

Table 1. Demographic data 1995. (From Statistics, Sweden, <http://www.scb.se>)

	Sweden	Burlöv Community
Age distribution (%)		
0–15 years	22	21
16–64 years	61	65
65+ years	17	14
Population change/1000	+ 2.3	+ 8.7
Non-Swedish citizenship (%)	6	17
Mean income (SEK)		
(16–64 year of age)	151,000	148,000
Increase in mean income (%)		
(1992–98)	31.9	25.9
Unemployment (%)		
(16–64 year of age)	6.7	6.5
Education (%) (25–64 years of age)		
Elementary school	14	16
Junior high school	12	17
High school 2 years	34	34
High school 3 years	12	13
University < 3 years	14	10
University \geq 3 years	12	8

Table 2. Patient characteristics.

	Type 1 (<i>n</i> = 39)	Type 2 (insulin) (<i>n</i> = 96)	Type 2 (oral treatment) (<i>n</i> = 85)	Type 2 (diet only) (<i>n</i> = 44)
Age (years)	40 ± 13	64 ± 13	67 ± 12	65 ± 13
Age at onset (years)	16 ± 8	51 ± 13	57 ± 12	61 ± 13
Duration (years)	24 ± 16	13 ± 10	9 ± 7	3 ± 3
HbA _{1c} (%)	8.1 ± 1.5 (90%)	8.2 ± 2.0 (76%)	7.5 ± 1.5 (82%)	6.2 ± 1.4 (84%)
SBP (mmHg)	134 ± 18 (90%)	149 ± 2 (83%)	152 ± 18 (91%)	149 ± 22 (86%)
DBP (mmHg)	78 ± 7 (90%)	81 ± 14 (83%)	82 ± 8 (91%)	82 ± 9 (86%)
Antihypertensive medication (n)	7/35 (90%)	51/78 (81%)	44/80 (94%)	18/37 (84%)
BMI (kg/m ²)	25 ± 4 (90%)	28 ± 6 (50%)	30 ± 5 (45%)	28 ± 5 (39%)
U-Albumin (mg/L)	9 (0–250) (90%)	4 (0–4050) (75%)	0 (0–347) (87%)	0 (0–60) (80%)
S-Creatinine (µmol/L)	68 (49–125) (90%)	77 (44–601) (82%)	74 (44–200) (89%)	68 (44–119) (82%)

Percentages within brackets represent the proportion of data available in 264/268 patients. In 4/268 patients type of diabetes or treatment were unknown.

Values represent mean ± SD, and median (range) for u-albumin and s-creatinine.

SBP = systolic blood pressure; DBP = diastolic blood pressure; BMI = body mass index.

were performed for identification of independent risk factors (SPSS 10.0 for Windows). Fisher's exact test was used for testing differences of proportions between groups.

Results

Patient characteristics for those included in the present study are presented in Table 2. Data on age, age at onset and duration of diabetes were available for all patients. For other variables, data were available for 39–90% of patients (Table 2). A total of 102 patients were excluded from the study due to lack of data on fundus examinations during the 2 years of the study period.

Fundus examinations and screening intervals

Of 266 patients, 32 had been diagnosed with diabetes within a 2-year period prior to fundus examination and thus did not need more than one examination according to our programme protocol. Of the remaining 234 patients with either type 1 (*n* = 39) or type 2 (*n* = 195) diabetes, 93% (218/234) fulfilled the screening programme, with at least two examinations within a 5-year period of the programme. All type 1 diabetic patients (39/39) were examined according to the programme, as were 179 of 195 type 2 diabetic patients, 84/88 of whom were on insulin, 74/80 of whom were on oral treatment, 19/25 of whom were on diet treatment only, and 2/2 whose treatment was unspecified. Only 7% of subjects (16/234) had been

examined less often than at the anticipated 2–2.5-year intervals.

Laser treatment and vitrectomy

A total of 79 eyes in 50 patients had received laser treatment, focal and/or grid alone (*n* = 35), panretinal photocoagulation in combination with focal/grid treatment when appropriate (*n* = 44). Vitrectomy had been performed in an additional four eyes.

Visual acuity

The numbers of eyes and patients found to be either blind or visually impaired due to diabetic retinopathy in relation to type of diabetes are given in Table 3. None of the type 1 diabetic patients and only three of the type 2 diabetic patients, two on insulin and one on oral treatment, were blind (VA ≤ 0.1) due to diabetic retinopathy. The proportion of visually impaired eyes was higher among patients

with insulin-treated type 2 diabetes than among those on oral treatment and those on diet alone (*p* = 0.006 in both cases). In one eye in one type 1 diabetic patient, visual impairment was related to cataract rather than to diabetic retinopathy. In type 2 diabetic patients, other causes of visual impairment, including cataract and macular degeneration among others, were present in 51 eyes with no retinopathy or with mild to moderate diabetic retinopathy without macular oedema. The proportions varied between 0 and 5% in the different treatment groups.

Type 2 diabetic patients with sight-threatening diabetic retinopathy in at least one eye were older (*p* = 0.042), tended to have been younger at diabetes diagnosis (*p* = 0.015) and therefore to lived with diabetes for a longer time since diagnosis (*p* < 0.001). They also tended to have higher HbA_{1c} levels (*p* = 0.029), and higher s-creatinine levels (*p* = 0.032)

Table 3. Frequency of visual impairment due to diabetic retinopathy.

	Type 1	Type 2 (insulin)	Type 2 (oral treatment)	Type 2 (diet only)
	39 patients 78 eyes	96 patients 192 eyes	85 patients 170 eyes	44 patients 88 eyes
Visual acuity 0.2–0.4 number of patients (x) number of eyes (y)	(<i>x</i> = 2) (<i>y</i> = 5)	(<i>x</i> = 2) (<i>y</i> = 13)	(<i>x</i> = 0) (<i>y</i> = 2)	(<i>x</i> = 0) (<i>y</i> = 0)
Visual acuity ≤ 0.1 number of patients (x) number of eyes (y)	(<i>x</i> = 0) (<i>y</i> = 3)	(<i>x</i> = 2) (<i>y</i> = 7)	(<i>x</i> = 1) (<i>y</i> = 3)	(<i>x</i> = 0) (<i>y</i> = 1)

Differences regarding total numbers of blind and visually impaired eyes in 264/268 patients. In 4/268 patients type of diabetes or treatment were unknown.

Type 2 insulin versus oral treatment *p* = 0.0061

Type 2 insulin versus diet only *p* = 0.0057

Table 4. Patient characteristics in 226/227 type 2 diabetic patients: a comparison between those with and without sight-threatening diabetic retinopathy in at least one eye.

	Sight-threatening retinopathy (n = 37)	No sight-threatening retinopathy (n = 189)
Age (years)	69 ± 11 ^a	64 ± 12
Age at onset (years)	51 ± 12 ^e	56 ± 13
Duration (years)	18 ± 9 ^f	8 ± 7
HbA _{1c} (%)	8.2 ± 1.5 ^d	7.4 ± 1.9
SBP (mmHg)	157 ± 23 ^b	149 ± 20
DBP (mmHg)	80 ± 11	82 ± 11
Antihypertensive medication (n)	21/33	91/162
BMI (kg/m ²)	28 ± 7	29 ± 5
U-Albumin (mg/L)	3 (0–4050)	0 (0–347)
S-Creatinine (µmol/L)	91 (59–601) ^c	71 (44–200)
Insulin treatment (n)	28	67
Oral treatment (n)	8	77
Diet only (n)	1	43

Data on visual acuity was missing in 1/227 patients.

Values represent mean ± SD, or median (range) for u-albumin and s-creatinine.

^ap = 0.042, ^bp = 0.032, ^cp = 0.030, ^dp = 0.029, ^ep = 0.015, ^fp < 0.001

SBP = systolic blood pressure; DBP = diastolic blood pressure; BMI = body mass index.

than those without sight-threatening diabetic retinopathy in at least one eye (Table 4). Age at onset, duration of diabetes, and HbA_{1c} were independently related to sight-threatening retinopathy.

All type 2 diabetic patients with sight-threatening retinopathy and at least one eye with visual impairment (VA < 0.5) due to diabetic retinopathy had fulfilled the requirements of the screening programme. They were older (p < 0.001) at the time of the study and had been younger at diabetes diagnosis (p = 0.037) than those with VA ≥ 0.5 in both eyes (Table 5). Only age was independently related to visual impairment. It is noteworthy that 22/37 patients in the screening programme with sight-threatening retinopathy ended up with impaired VA in at least one eye.

Visual impairment and treatment of diabetic retinopathy in type 2 diabetes

Out of 15 eyes with visual impairment (VA 0.2–0.4), six had been treated for macular oedema alone and nine for a combination of macular oedema and severe non-proliferative or proliferative retinopathy. Corresponding figures for 11 blind eyes (VA ≤ 0.1) were four and three, respectively. In addition, vitrectomy had been performed in two blind eyes. Among those eyes with sight-threatening retinopathy and VA ≥ 0.5, 17 had been treated for macular oedema alone, one was on a waiting list for treatment, and 16 had undergone panretinal photoco-

agulation in combination with focal/grid treatment for macular oedema.

Discussion

The present study on the evaluation of a screening programme for early detection of treatable diabetic retinopathy in a geographically defined population identified 374 diabetic patients, comprising 2.6% of the population in one Swedish community. This figure is slightly lower than

the estimated prevalence of 3% in the region (Bitzén & Scherstén 1986) and we cannot exclude the possibility that some otherwise eligible subjects may have attended private general practitioners or may not have seen any doctor at all.

The study was confined to one community, which was comparable to the entire country in terms of age distribution and employment levels. However, its mean income was slightly lower, its population net increase was higher, and the number of inhabitants with non-Swedish citizenship was considerably higher than for Sweden as a whole, even exceeding the mean for the three big city areas of Stockholm, Gothenburg and Malmö (9%). Furthermore, there was a trend towards lower levels of education. Thus, the implementation of the screening programme may have been hindered by cultural differences and low socio-economic status. It has been shown that low levels of education and low income are associated with cataract, cataract surgery and impaired vision (Klein et al. 1994), and patients with diabetes without college education seem to develop proliferative retinopathy more often than those with tertiary education (Chaturvedi et al. 1996). Based on education levels and socio-economic status, the population of the present study may have been less willing to attend regular examinations and more prone to visual impairment than other more homogenous populations with higher levels of education.

Of the 374 patients identified as having

Table 5. Patient characteristics for type 2 diabetic patients with sight-threatening retinopathy: a comparison of patients with VA < 0.5 in at least one eye and patients with VA ≥ 0.5 in both eyes.

	Visual acuity ≥ 0.5 in at least one eye (n = 22)	Visual acuity ≥ 0.5 in both eyes (n = 15)
Age (years)	74 ± 7 ^a	61 ± 10
Age at onset (years)	54 ± 11 ^b	46 ± 11
Duration (years)	20 ± 9	15 ± 7
HbA _{1c} (%)	8.4 ± 1.7	8.0 ± 1.1
SBP (mmHg)	158 ± 25	157 ± 21
DBP (mmHg)	80 ± 11	81 ± 11
Antihypertensive medication (n)	14/21	7/12
BMI (kg/m ²)	28 ± 8	28 ± 5
U-Albumin (mg/L)	3 (0–4050)	3 (0–125)
S-Creatinine (µmol/L)	99 (60–601)	76 (59–228)
Insulin treatment (n)	17	11
Oral treatment (n)	4	4
Diet only (n)	1	0

Values represent mean ± SD, or median (range) for u-albumin and s-creatinine.

^ap < 0.001, ^bp = 0.037

SBP = systolic blood pressure; DBP = diastolic blood pressure; BMI = body mass index.

been diagnosed with diabetes, 72% participated in the screening programme. While this rate of participation is lower than in comparable studies, it should be noted that 93% of these subjects fulfilled the programme's requirements, representing a higher proportion of study subjects to do so than in previous studies of homogenous Nordic populations (Agardh et al. 1993; Henricsson et al. 1996; Kristinsson et al. 1997). Lack of ophthalmological examinations was evident only among patients with type 2 diabetes. We cannot exclude the possibility that the proportion of patients with sight-threatening retinopathy and visual impairment may have been different (i.e. higher) in those who did not have any ophthalmological examination. However, in a country like Sweden, with a state health care system, it seems unlikely that diabetic patients suffering from severe visual impairment would not see a doctor. Thus, we speculate that the frequency figures given in the present study are unlikely to be too low.

Eight years after the institution of the screening programme, the prevalence of blindness for type 1 diabetic patients was 0%, and for type 2 diabetic patients only 1%. Although the numbers of patients in this study are limited, particularly those with type 1 diabetes, the results of this study on a geographically defined population show that patients offered regular fundus screening examinations, followed by laser treatment when appropriate, rarely develop blindness due to diabetic retinopathy. The results are in accordance with those of other Nordic studies on small homogenous populations (Agardh et al. 1993; Kristinsson et al. 1994a,b; Henricsson et al. 1996). Compared to figures for the prevalence of blindness and visual impairment reported during the 1980s (Nielsen 1982; Jerneld & Algvare 1987; Sjölie & Green 1987), the results of the present study and others during the 1990s are encouraging. On a larger scale, Bäcklund et al. (1997) found that the number of newly blind patients referred to low vision rehabilitation centres in Stockholm County, Sweden, decreased by one-third during a 15-year period after a mass mailing to people with diabetes urging them to have retinal examination. In contrast, Porta et al. (1995) were unable to demonstrate decreased registration of blindness in northwest Italy between 1967 and 1991, despite the introduction of screening programmes for diabetic retinopathy. Recently, however, Porta et al.

(2001) reported a decreased incidence of blindness in type 1 diabetic patients, although blindness in type 2 diabetes, particularly among elderly patients, remained constant.

Despite screening and laser treatment, blindness and visual impairment could not be avoided, particularly in type 2 diabetic patients with macular oedema. Impaired VA in this patient group was found to be associated with older age, but not with other risk factors such as longer duration of diabetes, degree of metabolic control and blood pressure levels. Thus, despite early diagnosis and treatment, impaired VA in type 2 diabetes is most likely due to unsuccessful laser treatment in older type 2 diabetic patients with macular oedema. This accords with the results obtained by Porta et al. (2001). Sight-threatening retinopathy per se, regardless of VA, was associated with some well-known risk factors, such as age at onset and duration of diabetes, as well as with degree of metabolic control (Aiello et al. 2001). Systolic blood pressure was not an independent risk factor.

In summary, the present study on a geographically defined population suggests there are beneficial effects in screening for and laser treatment of diabetic retinopathy in both type 1 and type 2 diabetes. It also identifies a subgroup of older type 2 diabetic patients in whom VA cannot be preserved, probably due to unsuccessful photocoagulation of diabetic macular oedema.

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