Prevalence and Risk Factors for Diabetic Retinopathy in the Multiethnic Population of Mauritius


This study examines the prevalence of, and risk factors for, diabetic retinopathy in Asian Indian, Chinese, and Creole Mauritians in whom there is an increasing prevalence of non-insulin-dependent diabetes mellitus (NIDDM). As part of a population-based survey on the Indian Ocean island of Mauritius in 1992, glucose tolerance was classified using a 75-g oral glucose tolerance test on 6,553 persons. Subjects with newly diagnosed (n = 358) or known diabetes (n = 388), and a random sample of one in four subjects with impaired glucose tolerance (n = 165), had stereoscopic 45° retinal photographs taken of three fields in the right eye after mydriasis. Photographs were graded according to a modified version of the Airlie House criteria. The prevalence of nonproliferative and proliferative retinopathy was: 14.5% and 0.3%, respectively, in newly diagnosed diabetic subjects; 42.0% and 2.3%, respectively, in known diabetic subjects; and 9.1% and 0%, respectively, in persons with impaired glucose tolerance. Muslim Indians had the lowest prevalence of retinopathy (10.8% and 34.0% for new and known diabetes, respectively), but after adjusting for other factors, this was significantly different only to Creoles (18.8% and 53.8%, respectively). Univariate analysis revealed significant differences between diabetic subjects with and without retinopathy in mean age, body mass index, fasting and 2-hour plasma glucose levels, systolic and diastolic blood pressure, fasting triglycerides, serum creatinine, and urinary albumin levels. For known diabetes, mean duration of diabetes and the proportion using insulin were also greater in those with retinopathy. Multivariate analysis using logistic regression confirmed that increasing duration of diabetes, fasting plasma glucose, systolic blood pressure, and urinary albumin concentration, and decreasing body mass index, were independently associated with retinopathy. The high prevalence of diabetic retinopathy observed in all major ethnic groups in Mauritius portends a serious public health problem, given the relative recency of the NIDDM epidemic in that country and the limited resources for laser photocoagulation. Strategies to minimize this problem among those already known to have diabetes should include strict control of plasma glucose and blood pressure. Am J Epidemiol 1998;147:448-57.

Diabetic retinopathy is the leading cause of blindness in developed countries (1). In many developing countries the incidence and prevalence of non-insulin-dependent diabetes mellitus (NIDDM) far exceed rates in the developed world (2), but facilities for the detection and treatment of retinopathy are limited. Consequently, diabetic retinopathy has the potential to become a serious public health problem in these populations. Few studies of diabetic retinopathy have used standardized criteria for case definition, and population-based studies have been confined mainly to developed countries. The multiethnic and rapidly developing population of Mauritius has a high prevalence of NIDDM, even in young adults (3). In this paper, we report the results of a population-based study of diabetic retinopathy using standardized photographic methods (4) in Indian, Creole, and Chinese Mauritians.
MATERIALS AND METHODS

Background and study population

Mauritius is an independent island nation situated in the Indian Ocean 800 km east of Madagascar. Approximately 70 percent of the population are of Indian (Hindu and Muslim) ethnic origin, 2 percent are Chinese, and the majority of the remaining 28 percent are Creoles, being predominantly of African and Malagasy ancestry with some European admixture. The 1992 Mauritius noncommunicable disease survey was performed in 14 geographically defined population clusters, 11 of which had been investigated in an earlier survey in 1987 (3, 5). The overall response rate in 1992 was 89.1 percent, with 6,553 attenders. A major aim of the study was to investigate the complications of NIDDM in Mauritians, and retinal photographs were taken for the first time in 1992.

During the baseline (1987) survey, 10 population clusters were randomly selected and one area was purposively selected for its high concentration of Chinese residents, as described previously (3). In 1992, an additional three clusters were selected for their predominant ethnic group, making a total of 10 randomly chosen areas and four ethnically selected areas (Chinese plus Hindu, Muslim, and Creole). In the original 11 clusters, all resident adults aged 25—74 years were invited to attend. In the three new clusters, stratified sampling was used to select equivalent numbers of men and women in three age strata (35–44, 45–54, and 55–64 years) (5).

Survey procedure

The following procedures were carried out on all participants as described previously (3, 5–7): measurement of height and weight, and waist and hip circumferences; systolic and fifth phase diastolic blood pressure measurements in duplicate using a standard mercury sphygmomanometer; and an interviewer-administered medical history questionnaire in Creole (the lingua franca). All subjects not on diabetic medication had a 2-hour 75-g (dextrose monohydrate) oral glucose tolerance test (8). Fasting and 2-hour venous blood samples were centrifuged and separated immediately, and plasma glucose was measured on site using YSI glucose analyzers (Yellow Springs Instrument Company, Yellow Springs, Ohio) within 3 hours of collection. Fasting triglycerides, total cholesterol, and creatinine levels were measured in serum at the Central Laboratory, Mauritius, using an automated Chemistry Profile Analyzer (Model LS) (Coultronics, France).

Hypertension was defined according to World Health Organization criteria (9) as a mean diastolic blood pressure ≥95 mmHg or a mean systolic blood pressure ≥160 mmHg and/or treatment with hypotensive drugs (6). Diabetes was defined according to World Health Organization criteria (3, 5, 8). Briefly, subjects reporting a history of diabetes had "known" diabetes if they were currently taking oral agents or insulin, or if they had a fasting plasma glucose ≥7.8 mmol/liter or a 2-hour plasma glucose ≥11.1 mmol/liter. "New" diabetic subjects were those without a diabetic history who had a 2-hour plasma glucose ≥11.1 mmol/liter, or in the absence of a 2-hour sample, a fasting plasma glucose ≥7.8 mmol/liter. Impaired glucose tolerance was defined by 2-hour plasma glucose ≥7.8 mmol/liter and <11.1 mmol/liter, and subjects with normal glucose tolerance had a 2-hour plasma glucose concentration <7.8 mmol/liter.

Retinopathy subsample

All new or known diabetic subjects and every fourth subject with impaired glucose tolerance from the original 11 survey clusters were eligible for the retinopathy study. These subjects were transported by bus from each of the field survey sites to the National Eye Hospital at Moka within a few days of their glucose tolerance tests. Distant visual acuity was assessed before mydriasis using a Snellen chart. First morning clean urine samples were also collected from subjects eligible for the retinopathy substudy, and albumin concentration was determined by an in-house radioimmunoassay (10) (interassay coefficient of variation = 5.0 percent, intraassay coefficient of variation = 2.4 percent) on samples transported frozen to Newcastle Upon Tyne, United Kingdom.

After excluding subjects who could not be photographed, or whose photographs were not gradable, valid retinopathy data were available for 340 known diabetic subjects, 324 newly diagnosed diabetic subjects, and 165 subjects with impaired glucose tolerance, which represents 83, 81, and 74 percent, respectively, of those eligible in each status of glucose tolerance from the main survey sample. In addition, retinal photographs were taken and visual acuity assessed in 48 known and 34 newly diagnosed diabetic subjects from the 12th survey area. For logistic reasons, retinal photographs could not be taken in the final two survey areas. Therefore, a total of 911 subjects from 12 survey areas had valid retinal photographs, and are the focus of this report.

Stereoscopic 45° retinal photographs in three overlapping fields of the right eye only were taken using a Topcon TRC-50VT camera (Topcon Corporation, Tokyo, Japan). The left eye was used if it was not possible to photograph the right retina. The three photographic fields (with overlap) were: centered on the
optic disc; macula (temporal to the optic disc); and nasal to the disc. Photographs were graded by a trained and certified assessor (W.P.) masked to all subject information. Photographs were compared with Airlie House reference photographs, and a level of severity of diabetic retinopathy was assigned by a modification of the 191 system (4). Photographs for every tenth subject were later regraded by the same assessor to ensure internal validity. The gradings were categorized for the purposes of this study into: no diabetic retinopathy (levels 10–15); nonproliferative retinopathy (levels 20–55); and proliferative diabetic retinopathy (levels 61–85).

Statistical analysis

Analyses were performed using the Statistical Package for the Social Sciences (SPSS PC+) (11). Prevalence estimates were age-standardized by the direct method (12) using the diabetic population from the 1987 survey in 10-year age-bands as standard. Analyses of risk factor associations have been limited to newly diagnosed and known diabetic subjects. Differences in mean values were compared using t tests and proportions were compared with the $\chi^2$ test. Measures of glucose, triglycerides, serum creatinine, and urine albumin were loge-transformed to normalize distributions for analysis, and results were back-transformed for presentation as geometric means in the tables. Tertiles of body mass index were calculated from the whole survey population. Trends in proportions were assessed using the $\chi^2$ test for linear trend (12, 13).

Multiple logistic regression was used to assess the independent effect of the following parameters on the presence of retinopathy: age, sex, ethnic group, duration of diabetes, fasting plasma glucose, total serum cholesterol, fasting serum triglycerides, urinary albumin, body mass index, waist-hip ratio, age at diagnosis, systolic blood pressure, smoking status, and alcohol consumption. Categories are further described in the tables. A forward stepwise selection procedure was used with a $p$ value of 0.05 as the criterion for entry of the variables. Regression analyses were performed for all subjects with diabetes, and then separately for new and known diabetes.

**RESULTS**

The prevalence of diabetic retinopathy according to glucose tolerance status is shown in table 1. There was no proliferative disease among the impaired glucose tolerance group, although 9.1 percent had nonproliferative retinopathy. Overall, 28.8 percent of diabetic subjects had nonproliferative retinopathy and 1.3 percent had proliferative disease. The prevalence of reti-

<table>
<thead>
<tr>
<th>Glucose tolerance</th>
<th>No.</th>
<th>Non-proliferative (%)</th>
<th>Total (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impaired glucose tolerance</td>
<td>625</td>
<td>12.9</td>
<td>6.5–21.2</td>
</tr>
<tr>
<td>New diabetes</td>
<td>176</td>
<td>17.8</td>
<td>6.3–43.0</td>
</tr>
<tr>
<td>Known diabetes</td>
<td>190</td>
<td>10.6</td>
<td>3.7–27.6</td>
</tr>
<tr>
<td>All diabetes</td>
<td>721</td>
<td>10.6</td>
<td>5.7–19.8</td>
</tr>
</tbody>
</table>

* CI, confidence interval.
nopathy in known diabetic subjects was three times higher than in newly diagnosed cases. Women tended to have lower prevalences of total retinopathy than men in each class of glucose tolerance, but the differences were not significant.

Table 2 illustrates characteristics of the diabetic subsample according to retinopathy status. There were significant differences in a number of variables: subjects with retinopathy were older, had higher mean fasting and 2-hour plasma glucose, systolic and diastolic blood pressures, triglycerides, serum creatinine, and urinary albumin, and had lower mean body mass index. Among the known diabetic group, retinopathy was associated with longer mean duration of diabetes and with insulin treatment. Adjusting for duration and age did not appreciably change these results.

Among known diabetic subjects, the age-standardized prevalence of retinopathy was over 45 percent in Hindu Indian, Creole, and Chinese subjects, with a lower rate (30.6 percent) in Muslim Indians. Among newly diagnosed diabetic subjects, the prevalence of retinopathy varied from 3.8 percent in Chinese to 18.9 percent in Creoles. When all diabetic subjects were considered together, Muslim rates remained the lowest overall (table 3). After stratification by fasting plasma glucose levels and duration, Muslims had a lower prevalence of retinopathy compared with other ethnic groups (combined) in all but one category (data not shown). Muslims and Chinese had higher ascertainment of diabetes than the other ethnic groups, with 55.4 percent and 56.1 percent, respectively, of all cases known, compared with 47.2 percent and 49.4 percent, respectively, among Hindus and Creoles. Among known diabetic subjects: insulin treatment was more common in Muslims (7.8 percent) than in Hindus (2.9 percent), Creoles (6.0 percent), or Chinese (6.3 percent); "poor control" (fasting plasma glucose concentration ≥11.1 mmol/liter) was less frequent in Muslims (26 percent) and Chinese (22 percent) than in Hindus (39 percent) and Creoles (47 percent); but mean duration and mean age at diagnosis varied little between ethnic groups (data not shown).

The prevalence of any retinopathy increased significantly with duration of diabetes (χ² test for trend = 127, p < 0.0001) and with increasing fasting plasma glucose (χ² test for trend = 40.3, p < 0.0001) (table 4). Over 50 percent of subjects with self-reported duration of 5 or more years had retinopathy. Hypertensive subjects had a generally higher prevalence of retinopathy than nonhypertensive subjects even after stratification by fasting plasma glucose and duration categories (table 5) or albuminuria status (figure 1). The prevalence of retinopathy also increased with rising levels of urinary albumin concentration irrespective of hypertension status (figure 1). Overall, 75 percent of subjects with macroalbuminuria had retinopathy.

Greater weight loss in more severe diabetes may have confounded the relation between body mass index and retinopathy, so the data were stratified by new and known diabetes (figure 2). The inverse relation between retinopathy and body mass index was clearly stronger in known diabetic subjects (χ² for trend = 13.9, p < 0.001) than in newly diagnosed subjects (χ² for trend = 2.2, p = 0.14). By contrast, there was no relation between waist-hip ratio and retinopathy (data not shown).

For combined new and known diabetic subjects, multiple logistic regression revealed that duration of diabetes, fasting plasma glucose, systolic blood pressure, urinary albumin, and body mass index (inversely) were independently associated with retinopathy (table 6). A known duration of 10 or more years carried an independent odds ratio for any retinopathy of 9.0, relative to newly diagnosed diabetes. High fasting plasma glu-

<p>| TABLE 2. Characteristics of diabetic subjects with and without retinopathy, Mauritius 1992 |
|-----------------------------------------------|----------------|-------------------------|--------|</p>
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No retinopathy</th>
<th>Retinopathy</th>
<th>p value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>All diabetes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>521</td>
<td>225</td>
<td></td>
</tr>
<tr>
<td>Male (%)</td>
<td>43.6</td>
<td>48.9</td>
<td>0.18</td>
</tr>
<tr>
<td>Age (years)</td>
<td>51.8</td>
<td>54.6</td>
<td>0.002</td>
</tr>
<tr>
<td>Age at diagnosis (years)</td>
<td>49.7</td>
<td>48.1</td>
<td>0.08</td>
</tr>
<tr>
<td>Visual acuity &lt;6/12 (%)</td>
<td>13.3</td>
<td>15.2</td>
<td>0.50</td>
</tr>
<tr>
<td>Current smoker (%)</td>
<td>19.2</td>
<td>16.2</td>
<td>0.34</td>
</tr>
<tr>
<td>Alcohol ≥3 units/day</td>
<td>7.9</td>
<td>4.5</td>
<td>0.09</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>26.7</td>
<td>25.7</td>
<td>0.004</td>
</tr>
<tr>
<td>Waist-hip ratio</td>
<td>0.91</td>
<td>0.92</td>
<td>0.09</td>
</tr>
<tr>
<td>Fasting plasma glucose (mmol/liter)*</td>
<td>8.4</td>
<td>10.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2-hour plasma glucose (mmol/liter)*</td>
<td>15.0</td>
<td>16.6</td>
<td>0.002</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>133</td>
<td>138</td>
<td>0.003</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>80</td>
<td>83</td>
<td>0.007</td>
</tr>
<tr>
<td>Total cholesterol (mmol/liter)</td>
<td>5.1</td>
<td>5.3</td>
<td>0.15</td>
</tr>
<tr>
<td>Fasting triglycerides (mmol/liter)*</td>
<td>1.92</td>
<td>2.13</td>
<td>0.03</td>
</tr>
<tr>
<td>Serum creatinine (µmol/liter)*</td>
<td>90</td>
<td>101</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Urinary albumin (µg/ml)*</td>
<td>2.33</td>
<td>4.66</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Known diabetes only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>216</td>
<td>172</td>
<td></td>
</tr>
<tr>
<td>Duration (years)</td>
<td>4.9</td>
<td>8.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Oral hypoglycemic treatment (%)</td>
<td>80.1</td>
<td>78.5</td>
<td>0.38</td>
</tr>
<tr>
<td>Insulin treatment (%)</td>
<td>2.3</td>
<td>8.1</td>
<td>0.006</td>
</tr>
<tr>
<td>Visual acuity &lt;6/12 (%)</td>
<td>7.1</td>
<td>7.1</td>
<td>0.99</td>
</tr>
<tr>
<td>Education (years)</td>
<td>5.2</td>
<td>5.3</td>
<td>0.70</td>
</tr>
</tbody>
</table>

* Geometric means.
† From χ² test for proportions and t test for means.
cose ("poor control") had an odds ratio of 2.9 relative
to "good control," and the odds of retinopathy were
1.2 for every 10 mmHg rise in systolic blood pressure.

For subjects with newly diagnosed diabetes only,
current age (equivalent to "age at diagnosis"), fasting
plasma glucose, systolic blood pressure, and male sex
conferring a significantly increased risk of retinopathy.
Among known diabetic subjects, duration, fasting
plasma glucose, systolic blood pressure, urinary albu-
min, and younger age at diagnosis were independently
associated with retinopathy.

When a variable comparing each ethnic group to
Muslims was forced into selected models, Creoles had
statistically significant odds ratios of 1.9 (95 percent
confidence interval (CI) 1.1–3.3) and 2.4 (95 percent
CI 1.2–4.8) for retinopathy in "all" and "known"
diabetes, respectively, relative to Muslims. Other eth-
nic comparisons were not significant: Hindus relative
to Muslims had an odds ratio of 1.5 (95 percent CI
0.9–2.5) for "all" and 1.7 (95 percent CI 0.9–3.1) for
"known" diabetes; and Chinese relative to Muslims
had an odds ratio of 1.0 (95 percent CI 0.4–2.2) for
"all" and 1.5 (95 percent CI 0.9–2.5) for "known"
diabetes.

DISCUSSION

Prevalence

We have shown previously that the prevalence of
NIDDM in Mauritius is high, and that it varies little
between ethnic groups (3). This study shows that di-
abetic retinopathy is also common in Mauritians, irre-
versible of ethnic background. To our knowledge,
there have been no other studies of diabetic retinop-
athy using standardized photographic methods in In-
dian, African-origin Creole, or Chinese populations.
Given that the NIDDM epidemic in Mauritius is rel-
atively recent, there is a high prevalence in young
adults, and there is a high proportion of newly diag-
nosed cases (3), the prevalence of retinopathy is likely
to increase in the future, as average duration of dia-
betes increases.

The overall prevalence of retinopathy in diabetic
Mauritians (30 percent) was higher than that found in
Nauruans (24 percent) using direct and indirect oph-
thalmoscopy (14), and similar to that determined using
a non-mydriatic camera in Pima Indians (34 percent)
(15). However, caution must be exercised when com-
paring prevalence determined by different methods,
particularly studies which have relied on opthalmos-
copy (16). Klein et al. (17) have demonstrated that
direct ophthalmoscopy through an undilated pupil has
an agreement of only 54 percent for grading of reti-
nopathy defined on the basis of stereoscopic photo-

| TABLE 3. Prevalence of proliferative and nonproliferative retinopathy by glucose tolerance status in four ethnic groups, Mauritius, 1992 |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Diabetes        | Non-diabetic    | Non-diabetic    | Non-diabetic    | Non-diabetic    |
|                 | Total*          | Total*          | Total*          | Total*          |
|                 | No. (%)         | No. (%)         | No. (%)         | No. (%)         |
| Hindu Indian    | 170 (10.5)      | 135 (10.9)      | 160 (11.8)      | 193 (12.0)      |
| Chinese         | 105 (9.0)       | 128 (11.6)      | 115 (10.7)      | 168 (12.0)      |
| Creole          | 343 (5.9)       | 248 (4.6)       | 228 (4.6)       | 262 (5.1)       |
| Muslim          | 305 (5.5)       | 242 (4.5)       | 224 (4.4)       | 251 (4.9)       |
| Total           | 923 (5.3)       | 733 (4.3)       | 683 (4.3)       | 814 (4.6)       |

† CI, confidence interval.

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graphs in three standard fields. However, after mydriasis and training of ophthalmoscopists agreement of 86 percent has been reported (18). Agreement of non-mydriatic photography with three standard stereoscopic fields was 82.5 percent (17).

As demonstrated in table 7, when comparison is limited to studies of known diabetes using retinal photographs graded according to the modified Airlie House classification (4), the prevalences of retinopathy in Indian, Creole, and Chinese Mauritians are broadly similar to levels in other populations. This includes Caucasians (19–21), Hispanic- (19) and Mexican-Americans (20), and Polynesians (22). Similarly, the prevalence determined using comparable photographic methods in newly diagnosed NIDDM detected on the basis of glucose tolerance tests in population-based studies are in general agreement. For example, our rates for diabetic retinopathy in the total sample of new NIDDM (15 percent), and more specifically Hindu Indians (18 percent), Muslim Indians (13 percent), Creoles (19 percent), and Chinese (4 percent), compare with 15 percent in Samoans (22), 16 percent in Mexican-Americans (20), and 14 percent in Caucasians (20).

However, variability in the distribution of age and disease duration, and remaining methodological differences including the number of photographic fields, the use of one versus two eyes, and whether levels 14 and 15 (exudates or hemorrhages without microaneurysm) (4) are classified as diabetic retinopathy, may still influence comparability of studies. Moss et al. (23) have previously shown good agreement (92 percent sensitivity) between classification of “any retinopathy” based on three versus seven photographic fields. Although their fields did not correspond with those used in the Mauritius study, our use of a wider angle lens ensured greater coverage of the retina, and our ascertainment of retinal lesions should, therefore, be high.

Because of the difficulties of direct comparison of rates between studies—even those using stereoscopic photographs and modified Airlie House grading—it is instructive to compare rates between ethnic groups determined within a single study by the same investigators. In Mauritius, Muslim Indians seemed to have lower susceptibility to retinopathy than Hindu Indians and Creoles, but after adjusting for other factors, only the latter difference remained statistically significant. However, the prevalence in the ethnically distinct Hindu Indians and Creoles was similar. These results suggest that nongenetic factors were most likely to explain the “ethnic” differences in prevalence. Fasting glucose levels are reasonably reliable indicators of long-term metabolic control in NIDDM (24). Muslim Indians had lower levels in this study than other ethnic groups, and the likelihood of better control was also supported by a higher ascertainment rate and more frequent insulin treatment. Nevertheless, the difference between Muslims and Creoles remained after controlling for other factors, including glucose levels and duration. The reason for the lower rates of retinopathy in newly diagnosed diabetic Chinese Mauritians is unclear, but may reflect better diabetes case-finding in Chinese, particularly given that rates in Chinese with known NIDDM were similar to those of other ethnic groups.

Evidence for ethnic differences in other studies is contradictory, and on the whole, also unconvincing. Harris et al. (25) found a marginally elevated risk of retinopathy in African-American men, but not women, compared with Caucasians. In the San Luis Valley study, non-Hispanic white known diabetic subjects had higher rates of duration-adjusted retinopathy than Hispanic subjects (19). By contrast, in another population-based study, retinopathy was more common in Mexican-Americans than in Caucasians (20). Haffner et al. (26) hypothesized that greater insulin resistance in Mexican-Americans might explain the apparent excess risk of retinopathy compared with Caucasians, but this cannot explain the Mauritian results, as Muslim Indians have the highest levels of basal and stimulated insulin (27).

### Risk factors

Duration of diabetes was the strongest risk factor for retinopathy in diabetic Mauritians. Compared with newly diagnosed subjects, those with a known duration of 10 or more years had a ninefold increased risk of retinopathy after controlling for glycemia and other risk factors. Duration has been consistently identified as a strong risk factor for retinopathy in cross-sectional

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<table>
<thead>
<tr>
<th>Duration (years)</th>
<th>No.</th>
<th>Non-proliferative</th>
<th>Proliferative</th>
<th>All retinopathy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newly diagnosed</td>
<td>358</td>
<td>14.5</td>
<td>0.3</td>
<td>14.8</td>
</tr>
<tr>
<td>1–4</td>
<td>176</td>
<td>27.3</td>
<td>1.7</td>
<td>29.0</td>
</tr>
<tr>
<td>5–9</td>
<td>106</td>
<td>45.3</td>
<td>0.0</td>
<td>45.3</td>
</tr>
<tr>
<td>≥10</td>
<td>105</td>
<td>63.8</td>
<td>5.7</td>
<td>69.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fasting plasma glucose (mmol/liter)</th>
<th>No.</th>
<th>Non-proliferative</th>
<th>Proliferative</th>
<th>All retinopathy</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;7.8</td>
<td>285</td>
<td>16.8</td>
<td>0.7</td>
<td>17.5</td>
</tr>
<tr>
<td>7.8–11.0</td>
<td>260</td>
<td>27.7</td>
<td>1.5</td>
<td>29.2</td>
</tr>
<tr>
<td>≥11.1</td>
<td>201</td>
<td>47.3</td>
<td>2.0</td>
<td>49.3</td>
</tr>
</tbody>
</table>

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(14, 16, 20–22) and longitudinal (28–30) studies. Duration most likely reflects a complex “summary” of long-term exposure to other known and putative risk factors, including glucose and blood pressure levels.

As discussed by Harris et al. (31), true onset of NIDDM may commonly occur several years before clinical diagnosis. This is reflected in the fact that retinopathy is common in subjects at the time of diagnosis, whether the latter occurs because of symptomatic presentation or through detection by screening asymptomatic individuals, as in this study.

Nonproliferative retinopathy was found in 9.1 percent of Mauritians with impaired glucose tolerance. This is similar to findings in a study of Samoans which used identical methods (22), and to results using other photographic regimes (32–34). Klein et al. (34) concluded that retinal blot hemorrhages or microaneurysms are observed at low frequency in the general population (including those with normal glucose tolerance) and may reflect other factors including blood pressure, age, and platelet count. It is also possible that some of the retinopathy observed in Mauritian subjects with impaired glucose tolerance may have been due to misclassification of, or improvement in, glucose tolerance or misgrading of retinal photographs.

We found a higher prevalence of diabetic retinopathy in men, and after controlling for other factors, this retained significance in those with newly diagnosed diabetes. Other studies have reported small excesses of retinopathy in Caucasian (26), Mexican-American (26), Samoan (22), and African-American (25) men, but in general, these differences appear to be explained by other risk factors.

After controlling for fasting glucose and other variables, current age was an important risk factor for retinopathy only in newly diagnosed Mauritian diabetic subjects, in whom it may have behaved as a surrogate marker of duration. Among known diabetic Mauritians, age at diagnosis was inversely and independently associated with retinopathy. A similar relation has been observed in other populations (19, 26, 22–24).
28), although age-at-diagnosis is not as strong a risk factor as disease duration.

The inverse relation between body mass index and retinopathy in Mauritians remained significant even after controlling for confounding by duration of diabetes, with which body mass index also has an inverse association. An inverse relation between body mass index and retinopathy has been found in several other studies (14, 16, 21, 22). It is likely that leanness is a marker for severity of diabetes, and, hence, exposure to prolonged hyperglycemia.

Hyperglycemia is clearly a major risk factor in the development of retinopathy in Mauritians, as demonstrated in both cross-sectional and longitudinal studies in several populations (14-16, 19-22, 28-30). In the absence of measures of glycated hemoglobin we have used a single fasting plasma glucose measurement as a marker for control. Although this may not reflect long-
term control as well as glycated hemoglobin (35), there is little difference between these tests as predictors of retinopathy in NIDDM (15, 24, 36). Tight control has been shown to reduce retinopathy in IDDM (37), and the randomized United Kingdom Prospective Diabetes Study is currently attempting to determine whether glycemic control can also reduce retinopathy in NIDDM (38).

The relation between systolic blood pressure and retinopathy is well recognized, and our results support those of previous studies (16, 19, 21, 39, 40). Although controlling for nephropathy (as urinary albumin concentration) weakened the association, systolic blood pressure remained an important risk factor for retinopathy in multivariate models. In IDDM, hypertension is nearly always associated with nephropathy (41), whereas in NIDDM hypertension is present in many people at diagnosis in the absence of nephropathy. The pathogenesis of renal microangiopathy may be very similar to that of retinal microangiopathy, and both may be accelerated by high blood pressure (42). The strong association between retinopathy and urinary albumin concentration in Mauritians has been observed in other populations (22, 43) and reinforces the importance of monitoring albumin excretion as a marker of vascular damage in diabetes. As Knowler et al. (39) have suggested, hypertension is an eminently modifiable risk factor for retinopathy in NIDDM patients. Mean blood pressure level and the prevalence of hypertension were lower in Muslim Indians than in other ethnic groups in Mauritius (6), perhaps contributing to the lower prevalence of retinopathy observed in Muslim Indians.

In conclusion, our study has shown relatively high levels of diabetic retinopathy in all ethnic groups in Mauritius, including asymptomatic subjects with diabetes diagnosed during screening. Independent risk factors identified were duration of diabetes, fasting plasma glucose, systolic blood pressure, leanness, and urinary albumin concentration. These results are of great significance given the extremely high and rising prevalence of NIDDM in Mauritius (5) coupled with the relatively early age of onset of diabetes and limited resources for tertiary preventive therapy through laser photocoagulation. As in other populations of the developing world with high rates of NIDDM, effective primary prevention, early detection of diabetes, and quality clinical care and education, focusing particularly on blood pressure and glycemic control, provide the key to averting an epidemic of blindness and other diabetic complications.

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