Awareness and Treatment of Dyslipidemia in Young Adults With Type 1 Diabetes

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OBJECTIVE — Dyslipidemia is a preventable major risk factor for coronary heart disease (CHD). Despite an increased risk of CHD in type 1 diabetes, little is known concerning awareness and adequacy of dyslipidemia treatment in this population. In this report, we describe the prevalence of dyslipidemia and adequacy of pharmacological treatment in patients with type 1 diabetes and comparable nondiabetic subjects.

RESEARCH DESIGN AND METHODS — From 2000 to 2002, the Coronary Artery Calcification in Type 1 Diabetes study obtained fasting lipid profiles in 1,416 individuals aged 19–56 years with no history of CHD: 652 type 1 diabetic patients (46% men, mean age 37 ± 9 years) and 764 nondiabetic control subjects (50% men, mean age 39 ± 9 years). These data combined with patient questionnaire results were used to determine prevalence of dyslipidemia and adequacy of pharmacological treatment. For all subjects, dyslipidemia was defined using National Cholesterol Education Program Adult Treatment Panel III criteria.

RESULTS — Type 1 diabetic subjects had significantly less dyslipidemia than nondiabetic control subjects (47 vs. 58%, $P < 0.001$), and a higher percentage of those with abnormal lipids were aware of (52 vs. 34%, $P < 0.0001$), on medication for (36 vs. 9%, $P < 0.0001$), and in control of their lipid levels (15 vs. 1.4%, $P < 0.001$). Of those on treatment, control was achieved in 41% of type 1 diabetic subjects and 15% of nondiabetic participants ($P < 0.01$).

CONCLUSIONS — Dyslipidemia, a major risk factor for CHD, remains largely undiagnosed and undertreated in high-risk populations, such as patients with type 1 diabetes.

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Coronary heart disease (CHD) is the leading cause of mortality in patients with type 1 diabetes (1,2). As in persons with type 2 diabetes and the general population, dyslipidemia is a significant risk factor for CHD for type 1 diabetic patients (3). Reports from the National Health and Nutrition Examination Survey (NHANES) 1999–2000 indicate that 55% of the U.S. general population and 51% of adults aged 20–59 years with diabetes have hypercholesterolemia (4,5). European data indicate a similar prevalence of 51% of type 1 diabetic adults with dyslipidemia in the EURODIAB study (6). Although lipid profiles in type 1 diabetic patients tend to be better than in patients with type 2 diabetes, recent studies (7–9) suggest a need for more aggressive lipid lowering in type 1 diabetic patients to decrease CHD risk. While some patients benefit from nonpharmacological interventions, including improvement of glycemic control, exercise, and weight loss, others may require medication to improve lipid levels. However, the available literature (6,10) suggests that dyslipidemia is undertreated in this high-risk population.

From March 2000 to April 2002, fasting lipid profiles were obtained as part of the ongoing prospective Coronary Artery Calcification in Type 1 Diabetes (CACTI) study in 1,420 people aged 19–59 years with no known history of CHD. Baseline CACTI data were analyzed to determine awareness, treatment with medication, and adequacy of control of dyslipidemia in this cohort of type 1 diabetic patients and comparable group of young adults without diabetes.

RESEARCH DESIGN AND METHODS

— The data presented in this report were collected as part of the baseline examination of 1,420 participants in the CACTI study. The design of the CACTI study has been previously described (11). Briefly, type 1 diabetic subjects recruited for the study generally had been diagnosed at <30 years of age, treated with insulin within 1 year of diagnosis, and had duration of type 1 diabetes ≥10 years. All subjects were recruited with criteria of age 20–55 years. All subjects were asymptomatic for CHD and had no history of coronary artery bypass graft, coronary angioplasty, or unstable angina. Blood pressure and proteinuria status were not used to determine study eligibility. A total of 109 subjects in this baseline cohort participated in a pilot

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Abbreviations: ADA, American Diabetes Association; ATP, Adult Treatment Panel; CACTI, Coronary Artery Calcification in Type 1 Diabetes; CHD, coronary heart disease; FPG, fasting plasma glucose; NHANES, National Health and Nutrition Examination Survey.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

study that had slightly different inclusion criteria (12). Four of 1,420 subjects were excluded from our analysis: one subject had a fasting plasma glucose (FPG) of 173 mg/dl and was subsequently diagnosed with type 2 diabetes, two participants were 58 (nondiabetic) and 59 (type 1 diabetic) years old, and a 19-year-old (type 1 diabetic) sibling of another study participant had only 4 years duration of diabetes. Therefore, the 1,416 participants, aged 19–56 years, included 652 men and women with type 1 diabetes and 764 nondiabetic control subjects.

Eighteen subjects diagnosed at age ≥30 years were part of the pilot study, were antibody positive, or had clinical courses supporting the diagnosis of type 1 diabetes. All type 1 diabetic subjects had been treated with insulin within 1 year of diagnosis. Mean disease duration was 23.2 ± 8.9 years on enrollment, with 12 subjects with type 1 diabetes duration of 4–9 years (most of whom originally enrolled in the pilot study and were kept in the larger cohort). Type 1 diabetic subjects were recruited from outpatient clinics at the Barbara Davis Center (52%), other endocrinology or subspecialty clinics (6%), Denver area Kaiser Permanente clinics (16%), or other sources (26%).

To compare the group of type 1 diabetic subjects with a control group with similar age, sex, and ethnicity distribution, 764 control adults (50% men) were recruited from spouses, friends, and neighbors of type 1 diabetic participants and from University of Colorado employees. While none of the 764 control subjects had a history of diabetes, one might expect to find individuals with undiagnosed (type 2) diabetes in this general population sample. Five (0.7%) of 764 control participants had an FPG between 126 and 140 mg/dl at baseline exam. Of those five, one was diagnosed with type 2 diabetes 3 years later, while none of the other four reported having diabetes at annual surveillance contacts, and three subjects who completed the 3-year follow-up visit had FPG <110 mg/dl and HbA_{1c} <6%. For the analyses, we retained these five subjects in the control group; excluding them would not significantly change the results.

Similar to type 1 diabetic participants, nondiabetic control subjects were asymptomatic for CHD; had no history of coronary artery bypass surgery, coronary angioplasty, or unstable angina; and were aged 20–55 years (mean age 39 ± 9 years). Demographic characteristics of the CACTI control group were similar to that of the general Colorado population based on 2000 U.S. Census data (13): men accounted for 50.0 vs. 50.0% and non-Hispanic whites for 84.0 vs. 84.8% of the study and Colorado population aged ≥18 years, respectively. To evaluate the representativeness of the CACTI control subjects, their BMI, blood pressure, and FPG were compared with those of nondiabetic adults aged 20–55 years participating in the 2001–2002 NHANES (14). While CACTI control subjects were slightly older than NHANES participants (39 ± 9 vs. 36 ± 10 years), CACTI control subjects had slightly more favorable BMI (men: 27.2 ± 4.2 vs. 27.6 ± 5.7 kg/m^2, women: 25.0 ± 5.5 vs.28.1 ± 6.8 kg/m^2), total cholesterol levels (men: 197 ± 42 vs. 199 ± 43 mg/dl, women: 185 ± 34 vs. 199 ± 42 mg/dl), and systolic blood pressure (men: 118 ± 11 vs. 121 ± 14 mmHg, women: 111 ± 13 vs. 114 ± 15 mmHg) and similar FPG (men: 93 ± 11 vs. 92 ± 18 mg/dl, women: 87 ± 9 vs. 85 ± 13 mg/dl). The study protocol was approved by the Colorado Combined Institutional Review Board. Informed consent was obtained from all subjects before enrollment.

Definition of dyslipidemia

The National Cholesterol Education Program Adult Treatment Panel (ATP) III guidelines, established in 2001, were used to measure the prevalence of dyslipidemia and adequacy of treatment (15). Presence of dyslipidemia was defined by LDL ≥130 mg/dl, HDL <40 mg/dl, total cholesterol ≥200 mg/dl, or triglycerides ≥150 mg/dl. Subjects were also included as prevalent cases if they were on lipid-lowering medication at the time of the baseline visit but had normal lipid levels. Patient awareness of dyslipidemia was defined as a positive answer to the questions "has your doctor told you that you have high cholesterol?" or "has your doctor told you that you have high triglycerides?" or current use of lipid-lowering medication as indicated on the patient's survey response. Treatment was defined as current use of lipid-lowering medication, such as hydroxymethylglutaryl-CoA reductase inhibitors, bile acid sequestrants, fibric acid derivatives, or niacin. Diet modification and other lifestyle changes were not considered as treatments in this analysis. Control of dyslipidemia was defined as the absence of abnormal lipid levels defined by ATP III (stated above) in subjects on medication.

Laboratory analyses

Lipid profiles, including total cholesterol, triglycerides, and LDL and HDL cholesterol, were obtained after an overnight fast. Once collected, blood was centrifuged, and separated plasma was stored at 4°C overnight. Lab studies were performed in the General Clinical Research Center Core Laboratory at the University of Colorado Health Sciences Center. Total cholesterol and triglyceride levels were measured using standard enzymatic methods. HDL cholesterol was separated using dextran sulfate, and LDL cholesterol was calculated using the Friedewald formula (16). In addition to lipid levels, HbA_{1c} and FPG were also obtained. Urine albumin excretion was determined by the average of two timed overnight urine collections. As previously described (17), a standardized patient questionnaire was used to collect information on awareness and treatment of dyslipidemia as well as information on smoking status, diabetes duration, insulin dose, medication use, and medical history.

Statistical analysis

Statistical analysis was performed using SAS version 8.2 software (SAS Institute, Cary, NC). Demographic data were analyzed using two-sided *t* tests except when determining differences in proportions. Differences between type 1 diabetic and nondiabetic groups in prevalence, awareness, treatment, and control were analyzed using χ^2 tests (Table 1). Because triglyceride levels were not normally distributed, triglyceride levels were analyzed in the log-transformed scale (Tables 2 and 3). Differences in adjusted least-squares means were analyzed using ANOVA. *P* values <0.05 were considered statistically significant.

RESULTS — Clinical characteristics of the type 1 diabetic and nondiabetic control groups differed significantly in age, ethnicity, blood pressure, waist-to-hip ratio, fasting glucose, and prevalence of hypertension and proteinuria. Sex distribution, BMI, education, and smoking status were not significantly different (Table 1).

When stratified by sex and diabetes

Table 1—*Baseline characteristics of the study group*

	Type 1 diabetic group	Nondiabetic group	*P* value
n	652	764	—
Sex (% men)	46	50	0.11
Age (years)	37 ± 9	39 ± 9	<0.0001
BMI (kg/m^2)	26.2 ± 4.4	26.1 ± 5.0	0.64
Ethnicity (% non-Hispanic white)	94	84	<0.0001
Waist-to-hip ratio	0.82 ± 0.08	0.83 ± 0.09	0.02
Duration of diabetes (years)	23.2 ± 8.9	NA	—
Years of education (622 type 1 diabetic and 735 nondiabetic subjects)	16.0 ± 10.2	16.8 ± 9.9	0.19
Systolic blood pressure	117 ± 14	114 ± 12	<0.0001
Diastolic blood pressure	78 ± 9	79 ± 8	0.003
Hypertension	43	15	<0.0001
Current smoker	10.3	7.9	0.11
Ever a smoker	19.5	22.3	0.20
Albuminuria (micro/overt)	13.6/8.2	2.2/0.4	<0.0001
HbA_{1c}	8.0 ± 1.3	5.5 ± 0.5	<0.0001
Fasting blood glucose (mg/dl) [median (interquartile range)]	180 (113–253)	89 (83–96)	—
Glycemic control (HbA_{1c} < 7.5%)	36	NA	—
Continuous insulin infusion (pump use)	37	NA	—
Insulin dose (units · kg^{-1} · day^{-1})	0.61 ± 0.26	NA	—

Data are means ± SD or percent, unless otherwise indicated. Values were evaluated with Student's *t* test, and proportions were evaluated with χ^2.

status and adjusted for age and waist-to-hip ratio (Table 2), type 1 diabetic subjects had significantly lower average total cholesterol, LDL, and triglycerides and significantly higher HDL compared with nondiabetic subjects. When stratified by treatment and diabetes status and adjusted for age and waist-to-hip ratio (Table 3), type 1 diabetic subjects not on medication had significantly higher HDL and lower total cholesterol, LDL, and triglyceride levels compared with nondiabetic control subjects not on medication. Among subjects on lipid-lowering medication, those with type 1 diabetes had higher HDL cholesterol and lower total cholesterol, LDL, and triglyceride levels compared with nondiabetic control subjects.

Of the subjects reporting use of lipid-lowering medications, 96% (105 of 109) of type 1 diabetic participants were on hydroxymethylglutaryl-CoA reductase inhibitors (statins) compared with 80% (33 of 41) of nondiabetic control subjects ($P = 0.0013$). Of the remaining 12 subjects reporting use of lipid-lowering medications, 6 were treated with bile acid sequestrants, fibric acid derivatives, or niacin, and for 6 participants the type of lipid-lowering medication was not recorded.

Proportions of type 1 diabetic and nondiabetic subjects who were aware of, on medication for, and in control of their lipid levels are shown in Table 4. Type 1 diabetic patients had significantly less dyslipidemia (47 vs. 58%; $P < 0.001$), and a higher percentage of those with abnormal lipids were aware of, on medication for, or in control of their lipid levels ($P < 0.01$ for all comparisons). Of 109 type 1 diabetic and 41 nondiabetic subjects on lipid-lowering medication, 41% of type 1 diabetic and 15% of nondiabetic subjects had normal lipid profiles ($P < 0.01$). In age-stratified comparisons, the prevalence of dyslipidemia was significantly lower in type 1 diabetic compared with nondiabetic subjects in the age-group 30–39 years only. Proportions of type 1 diabetic subjects on medication and with normal lipid profiles were significantly higher than proportions of nondiabetic control subjects ($P < 0.001$).

These results were found using ATP III guidelines. Because data were initially obtained in 2000 and ATP III guidelines were published in 2001, data were reanalyzed using National Cholesterol Education Program ATP II guidelines, which were established in 1993 (18) and American Diabetes Association (ADA) guidelines (7). The prevalence of dyslipidemia was lowest using the ATP II guidelines (42% in type 1 diabetic vs. 50% in nondiabetic subjects; $P = 0.003$), higher with the ATP III (47 vs. 58%; $P < 0.001$), and the highest using the ADA guidelines (54 vs. 64%; $P < 0.001$). However, differences in prevalence, awareness, treatment, and control of dyslipidemia between type 1 diabetic and nondiabetic subjects did not change essentially when analyzed using ATP II or ADA guidelines.

CONCLUSIONS — Our findings indicate that a large number of both type 1 diabetic patients and young to middle-

Table 2—*Adjusted mean lipid levels (mg/dl) by sex and diabetes status, adjusted for age and waist-to-hip ratio*

	Men			Women		
	Type 1 diabetic group	Nondiabetic group	*P* value	Type 1 diabetic group	Nondiabetic group	*P* value
n	298	382	—	354	382	—
Total cholesterol	177 (172–181)	196 (192–199)	<0.0001	177 (173–180)	184 (181–187)	<0.01
LDL	105 (102–109)	122 (119–125)	<0.0001	98 (95–101)	106 (103–109)	<0.001
HDL	51 (50–53)	43 (42–44)	<0.0001	61 (59–62)	58 (56–59)	<0.01
Triglycerides*	87 (82–92)	128 (122–134)	<0.0001	81 (77–85)	92 (88–96)	<0.0001

Data are least-squares means adjusted for age and waist-to-hip ratio expressed as mean (95% CI). *Triglycerides analyzed in log scale and reported as geometric mean (95% CI).

Table 3—*Adjusted mean lipid levels (mg/dl) of subjects by treatment status, adjusted for age and waist-to-hip ratio*

	Not on treatment			On treatment		
	Type 1 diabetic group	Nondiabetic group	*P* value	Type 1 diabetic group	Nondiabetic group	*P* value
n	543	723	—	109	41	—
Cholesterol	178 (175–181)	188 (186–191)	<0.0001	172 (164–180)	207 (194–220)	<0.0001
LDL	103 (100–105)	113 (111–115)	<0.0001	98 (92–103)	120 (111–130)	0.0001
HDL	57 (56–58)	51 (50–52)	<0.0001	53 (50–56)	46 (42–51)	<0.01
Triglycerides*	82 (79–85)	106 (102–109)	<0.0001	96 (87–105)	148 (128–173)	<0.0001

Data are least-squares means adjusted for age and waist-to-hip ratio expressed as mean (95% CI). *Triglycerides analyzed in log scale and reported as geometric mean (95% CI).

aged nondiabetic adults are unaware of their current lipid levels. In addition, the majority of people diagnosed with abnormal lipids are not achieving desired lipid levels with current treatment. These results are comparable to recent surveys of the U.S. general population (4,19). In contrast, Perez et al. (10) identified dyslipidemia in 28% of type 1 diabetic subjects in a cohort in Spain. The study by Perez et al. used ATP II criteria to determine the prevalence of dyslipidemia and found 41.9% of subjects had LDL levels >130 mg/dl at baseline. Factors that may have contributed to a lower rate of dyslipidemia in the study by Perez et al. compared with type 1 diabetic subjects in the CACTI study include a younger average age (31 vs. 37 years in CACTI), lower BMI (22.6 vs. 26.2 kg/m^2 in CACTI), and shorter mean duration of diabetes (7.9 years vs. 23.2 years in CACTI). As the cohort examined by Perez et al. was in Spain, one would also expect differences in diet and lifestyle compared with our cohort in Colorado that could also affect prevalence of dyslipidemia.

Since the initial publication of National Cholesterol Education Program guidelines in 1988 (20), several reports have documented that Americans have become more knowledgeable about the importance of lipid control (4,19,21). Nash et al. (19) reported that although a large portion of the U.S. population is aware of the importance of normal cholesterol levels, less than half recognize that their own lipid levels are abnormal. Our data are consistent with these studies. While the type 1 diabetic group has more knowledge of abnormal lipids, many participants remain unaware or inadequately treated. Mean lipid levels by treatment status (Table 2) indicate that subjects on medications, regardless of diabetes status, had similar or worse lipid levels compared with subjects not on medication. Factors related to undertreatment of dyslipidemia may include abnormal lipids before starting medications, noncompliance, and inadequate medication doses. Regardless of the underlying reason, abnormal lipid levels observed in subjects on medication emphasize the need to monitor and intensify the level of treatment to adequately decrease CHD risk.

Despite lower cholesterol and LDL in type 1 diabetes, these patients are still at higher risk for CHD than the general population. When comparing lipid levels in the CACTI study to those reported by Saydah et al. (22) in a group of adults with mostly type 2 diabetes, our data document lower LDL and higher HDL levels in CACTI subjects with type 1 diabetes, even in those subjects not on medication. These data document that patients with type 1 diabetes have less dyslipidemia than patients with type 2 diabetes and the general population, yet still have similar or higher CHD risk. Favorable lipid profiles without significant reduction in CHD risk reinforces the idea that factors unique to type 1 diabetes are responsible for accelerated and more severe CHD observed in patients with type 1 diabetes. Physiologic explanations for less dyslipidemia in type 1 diabetes may include decreased hepatic synthesis of cholesterol (23). Other possible reasons for less dyslipidemia in type 1 diabetes in this study may include younger age of the type 1 diabetic group and more conscious lifestyle changes in patients with type 1 diabetes. For subjects on medication, closer monitoring of lipid profiles compared with nondiabetic subjects by health care providers and stricter guidelines for persons with diabetes, such as the ADA recommendations (7), may contribute to less dyslipidemia in subjects with type 1 diabetes. Further studies are needed to explain the paradox of less dys-

Table 4 —*Prevalence, awareness, treatment, and control of dyslipidemia in type 1 diabetic versus nondiabetic participants by age-group*

	Distribution		Prevalence of dyslipidemia		Aware		Treated		Controlled	
Age (years)	Type 1 diabetic group	Nondiabetic group	Type 1 diabetic group	Nondiabetic group	Type 1 diabetic group	Nondiabetic group	Type 1 diabetic group	Nondiabetic group	Type 1 diabetic group	Nondiabetic group
20–29	165	140	60 (37)	52 (37)	23 (38)*	9 (17)	13 (21)*	0 (0)	3 (5.0)	0 (0)
30–39	236	251	96 (41)*	142 (57)	50 (52)*	36 (25)	31 (32)*	12 (8)	13 (14)	1 (0.7)
40–49	185	257	104 (56)	167 (65)	58 (56)*	69 (41)	42 (40)*	20 (12)	15 (14)	3 (1.8)
≥50	66	116	44 (67)	81 (70)	26 (59)	36 (44)	23 (52)*	9 (11)	14 (32)	2 (2.4)
All	652	764	304 (47)*	442 (58)	157 (52)*	150 (34)	109 (36)*	41 (9.3)	45 (15)*	6 (1.4)

Date are *n* or *n* (%). *$P < 0.05$ for difference in proportion, type 1 diabetic vs. nondiabetic group.

lipidemia and higher mortality from CHD in type 1 diabetes.

Limitations of this study include use of the same lipids standards for type 1 diabetic and nondiabetic subjects. To uniformly compare all subjects to the same standard, ATP III guidelines for the general population were used to determine prevalence of dyslipidemia in the type 1 diabetic group instead of ADA guidelines. Because the same standards were used for both groups, we would expect a higher portion of type 1 diabetic patients to be aware and treated for dyslipidemia, considering that ADA recommendations and ATP III recommendations for diabetic patients are more aggressive than ATP III guidelines for nondiabetic subjects with no history of CHD. Although the type 1 diabetic group had lower prevalence and higher awareness of dyslipidemia, the data presented here demonstrate that many type 1 diabetic patients with dyslipidemia are unaware of their lipid levels and are not on lipid-lowering medication.

Selection bias may have been involved in the enrollment of both nondiabetic and type 1 diabetic participants. Because CACTI participants were evaluated with fasting lipid profiles, electrocardiogram, and electron beam computed tomography to determine coronary artery calcification, people concerned about their risk for CHD may have been more likely to enroll. To minimize selection bias and to control for difficult to quantify lifestyle risk factors, nondiabetic control subjects were mostly recruited from spouses or friends of type 1 diabetic patients. In fact, based on analysis of the 2000 census and NHANES data, the CACTI control population was remarkably representative of the general Colorado and U.S. adult population.

In the type 1 diabetic group, patients interested in a more detailed assessment of their risk for CHD, such as electron beam computed tomography, may have been more likely to participate, leading to an elevated number of type 1 diabetic subjects aware of their lipid levels and on medication. Because most type 1 diabetic subjects were recruited from tertiary care centers or endocrine practices rather than primary care offices, one might expect that the level of awareness and treatment with medication in our study population may be higher than among mainstream type 1 diabetic patients. If so, an even larger number of type 1 diabetic patients with dyslipidemia may be inadequately treated.

When lipid profiles were obtained at the baseline evaluation, all subjects were informed of their results and, at their request, had results sent to their managing physicians. Participants in the CACTI study are now being followed prospectively for at least 3 years. As longitudinal data are collected, assessment of changes in awareness, treatment with medication, and control at the follow-up evaluation may be informative.

In conclusion, more than half of otherwise healthy adults aged 20–55 years in Colorado had lipid level abnormalities. While the prevalence of dyslipidemia was slightly lower in subjects with type 1 diabetes, significantly more type 1 diabetic patients were aware of, on treatment for, and had control of their dyslipidemia compared with nondiabetic control subjects. Dyslipidemia, a major modifiable risk factor for CHD, remains largely undiagnosed and undertreated in both general and high-risk populations, such as type 1 diabetic patients. Efforts to increase public awareness and to treat dyslipidemia with medication should be maintained if not increased in both the general population and especially in patients with type 1 diabetes.

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