The Burden and Treatment of Diabetes in Elderly Individuals in the U.S.

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OBJECTIVE — To assess the prevalence of diabetes, distinguishing between elderly individuals with diabetes diagnosed in middle age ("middle age–onset diabetes") from elderly individuals with recently diagnosed diabetes ("elderly onset diabetes") and to assess the burden of complications and control of cardiovascular risk factors in these groups.

RESEARCH DESIGN AND METHODS — We analyzed data from 2,809 elderly individuals from the 1999–2002 National Health and Nutrition Examination Survey, a cross-sectional nationally representative survey of the civilian noninstitutionalized population of the U.S.

RESULTS — Among adults aged ≥65 years, the prevalence of diagnosed diabetes was 15.3%, representing 5.4 million individuals in the U.S. The prevalence of undiagnosed diabetes was 6.9% or 2.4 million individuals. Elderly individuals with middle age–onset diabetes had a much greater burden of microvascular disease but have a similar burden of macrovascular disease compared with individuals with elderly onset diabetes. Elderly individuals with middle age–onset diabetes had substantially worse glycemic control (proportion of individuals with HbA_{1c} >7% = 59.9%) compared with either elderly onset (41.6%) or nonelderly individuals with diabetes (55.3%). Individuals with elderly onset diabetes were also less likely to be taking glucose-lowering medications.

CONCLUSIONS — In this study, we documented a high prevalence of diabetes among elderly individuals and high rate of poor glycemic control in this population. Individuals with middle age– and elderly onset diabetes appear to represent distinct groups with differing burdens of disease and possibly differing treatment goals. Future studies of diabetes in elderly individuals may need to consider stratification based on age of diagnosis.

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The number of individuals aged ≥65 years in the U.S. is increasing markedly. People aged ≥65 years represented ~12% of the U.S. population in 2000 (~35 million people), and this proportion is expected to grow to almost 20% by the year 2020 (~55 million people) (1). The aging U.S. population poses great challenges to the health care system and clinical practice. Diabetes and its related problems of obesity, insulin resistance, and impaired glucose tolerance are growing problems in the U.S. The cumulative lifetime incidence of diabetes is estimated to be >30% (2). Age is a known risk factor for diabetes, but the epidemiology of the disease among elderly individuals has not been adequately characterized.

The objective of this study was to assess the prevalence of diabetes, distinguishing between elderly individuals with diabetes diagnosed in middle age ("middle age–onset diabetes") from elderly individuals with recently diagnosed diabetes ("elderly onset diabetes"). We hypothesized that the burden of micro- and macrovascular disease and treatment of diabetes would differ between these two groups. A secondary aim of this study was to investigate whether management of cardiovascular risk factors also differed between these groups.

RESEARCH DESIGN AND METHODS

This study was based on data from the 1999–2002 National Health and Nutrition Examination Survey (NHANES), an ongoing cross-sectional survey of the civilian, noninstitutionalized population of the U.S. Detailed in-person interviews, physical examinations, and serum samples were obtained from >21,000 individuals in the 1999–2002 survey. The eligible study sample consisted of 3,765 individuals aged 40–64 years and 2,809 individuals aged ≥65 years who were not missing information on diabetes status.

Assessment of diabetes

The NHANES standardized health examinations in the mobile examination centers (MEC) included measurement of height, weight, and blood pressure and collection of blood samples by trained personnel. Diagnosed diabetes was defined as a self-reported physician diagnosis. Individuals reporting "borderline diabetes" were considered nondiabetic. Age of diagnosis of diabetes was determined from the question, "How old were you when a doctor or health professional first told you that you had diabetes or sugar diabetes?" We defined individuals aged ≥65 years as elderly. Elderly individuals with diabetes diagnosed in middle age (aged 40–64 years) were classified as having middle age–onset diabetes and elderly individuals with recently diagnosed diabetes, i.e., diabetes diagnosed at age ≥65 years, were classified as having elderly onset diabetes. Undiagnosed diabetes was defined as a fasting glucose ≥126 mg/dl in the subsample of individuals without a diagnosis of diabetes who attended the morning examination session and were fasting ≥8 h.

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Abbreviations: ABI, ankle-brachial index; MEC, mobile examination center; 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.

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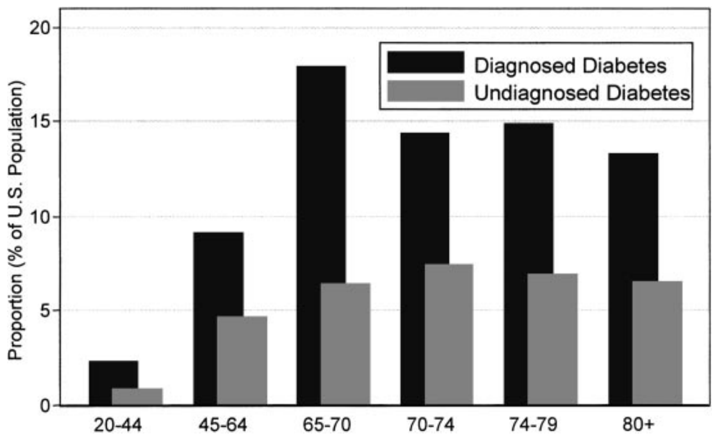

Figure 1—*Prevalence of undiagnosed and diagnosed diabetes by age-group, U.S. population, 1999–2002.*

Assessment of demographics, health conditions, and cardiovascular risk factors

Information on age, sex, race/ethnicity (categorized as non-Hispanic white, non-Hispanic black, Mexican American, or all other) and smoking status was based on self-report during the questionnaire portion of the survey. Smoking status was determined using answers to the questions, "Have you smoked at least 100 cigarettes in your life?" and "Do you now smoke cigarettes?" During the interview, participants were also asked questions regarding their history of cardiovascular disease. For the purposes of this study, prevalent cardiovascular disease was defined as a self-reported history of coronary heart disease, a previous heart attack, or a history of stroke. Retinopathy was also determined by self-report and was only assessed in individuals who reported a physician diagnosis of diabetes.

Subclinical peripheral artery disease can be determined with high sensitivity and specificity using the ankle-brachial index (ABI) (3,4). Ankle-brachial index measurements were obtained from NHANES 1999–2002 participants aged ≥40 years during the MEC exam. We defined peripheral arterial disease on the basis of an ABI measurement <0.90 in either leg (5).

Peripheral neuropathy was determined via monofilament testing of foot sensation and examinations for foot abnormalities and lesions by trained health technicians during the MEC examination. Peripheral neuropathy was defined as one or more insensate areas in either foot.

Hypertension was defined as a mean systolic blood pressure of ≥140 mmHg , a mean diastolic blood pressure of ≥90 mmHg, or a reporting of a physician diagnosis of high blood pressure. Mean blood pressure comprised up to four readings on two separate occasions. Hypertensive individuals who reported being prescribed medication for hypertension were categorized as having treated hypertension. Total cholesterol was measured enzymatically (6). Hypercholesterolemia was defined as a total cholesterol level ≥240 mg/dl, self-reports of a physician diagnosis of "high cholesterol," or self-reports that a physician had advised taking a cholesterol-lowering medication. Individuals who reported having been prescribed treatment for high cholesterol were categorized as having treated hypercholesterolemia. Detailed information regarding data collection in NHANES 1999–2002 is available elsewhere (6).

Statistical analysis

The NHANES surveys are ongoing, complex, multistage probability samples of the civilian, noninstitutionalized population of the U.S. The NHANES 1999–2002 survey oversampled elderly individuals, low-income individuals, adolescents, Mexican Americans, and non-Hispanic blacks to provide more reliable estimates for these population subgroups.

Analyses were performed using Stata version 8.2 (StataCorp, College Station, TX) svy commands to obtain unbiased estimates from the complex NHANES sampling design. SEs for all estimates were obtained using the Taylor series (linearization) method (6).

RESULTS

Prevalence of diabetes in elderly individuals

Among adults aged ≥65, the prevalence of diagnosed diabetes was 15.3% (SE 0.8); when applied to the 2000 U.S. Census population, this represents 5.4 million individuals. The prevalence of undiagnosed diabetes (fasting glucose ≥126 mg/dl) was 6.9% (SE 1.2), representing ~2.4 million individuals. Among elderly individuals with diagnosed diabetes, 60.6% (SE 3.1) and 39.4% (SE 3.1) had middle age–onset diabetes and elderly onset diabetes, respectively. Figure 1 displays the prevalence of undiagnosed and diagnosed diabetes by age-group. The distribution of self-reported age of diagnosis of diabetes among all participants (all ages) with diagnosed diabetes in NHANES 1999–2002 is shown in Fig. 2. The peak of the distribution is between ages 40 and 55, with a sharp decline after age 65, which may partially reflect differences in screening practices among elderly individuals.

Demographic characteristics

The characteristics of elderly and nonelderly adults with and without diabetes in the U.S population are displayed in Table 1. The mean age of elderly individuals with middle age–onset diabetes was 72 compared with 77 among individuals with elderly onset diabetes. African Americans were also disproportionately represented among the middle age–onset elderly diabetes group. Mean BMI and waist circumference were similar among individuals with middle age–onset and elderly onset diabetes.

Treatment characteristics

As shown in Table 2, mean fasting glucose was higher among elderly individuals with middle age–onset diabetes compared with elderly onset diabetes (172.4 vs. 132.3 mg/dl, $P = 0.001$). Indeed, elderly individuals with middle age–onset diabetes had higher fasting glucose values than nonelderly (aged 40–64 years) diabetic individuals (mean fasting glucose = 148.9 mg/dl). Similar trends were observed for glycemic control, as measured by HbA_{1c} (A1C). Middle age–onset elderly diabetic subjects had substantially worse glycemic control (proportion of individuals with A1C >7% = 59.9%) compared with either elderly onset diabetic subjects (41.6%, $P = 0.005$) or nonelderly diabetic subjects (55.3%).

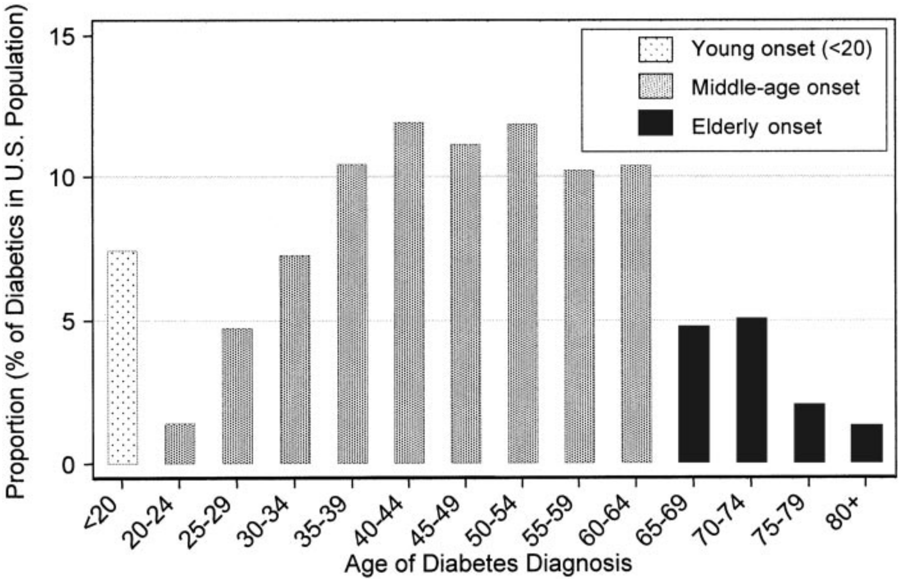

Figure 2—*Distribution of reported age of diabetes diagnosis in the U.S. population, 1999–2002.*

two elderly diabetic groups but was substantially higher than the prevalence among elderly individuals without diabetes or with middle age–onset diabetes. Whereas the prevalence of chronic kidney disease and peripheral neuropathy were similar among elderly individuals with middle age– and elderly onset diabetes, the prevalence of retinopathy was substantially higher in the middle aged–onset diabetic group (39.4 vs. 12.6%, $P < 0.001$). As will be discussed below, these prevalence estimates probably reflect the differential survival of the elderly individuals in the middle age– and elderly onset diabetic groups. Nonetheless, because the cut point of age 65 years to define elderly individuals is essentially arbitrary, we conducted sensitivity analyses to assess the impact of this definition. Similar results were obtained using other cut points between ages 60 and 70 years to define individuals as elderly (data not shown).

Elderly-onset diabetic subjects were also much less likely to be taking glucose-lowering medications (insulin, oral medications, or both) compared with elderly individuals whose diabetes was diagnosed in middle age. Of middle age–onset elderly diabetic subjects, 31.7% were currently receiving insulin alone compared with 6.9% of the elderly onset diabetic subjects ($P < 0.0001$). In a multivariable logistic regression model, these differences in medication use were not explained by age, sex, race, education, cognitive function, or measures of physical functioning (analysis not shown).

Burden of micro- and macrovascular disease

A history of stroke, coronary heart disease, and any cardiovascular disease were similar among the middle age– and elderly onset diabetic subjects aged ≥65 years. As might be expected, both of these groups had a substantially higher burden of cardiovascular disease compared with nonelderly diabetic subjects; any form of cardiovascular disease was more than twice as common among elderly than among nonelderly diabetic subjects. Peripheral arterial disease determined on the basis of a low ABI was similar in the

Control of cardiovascular risk factors

We also compared control of cardiovascular risk factors (hypertension, cholesterol, and smoking) across diabetes status in the nonelderly and elderly populations. Hypertension was extremely common (>80% prevalence) in elderly individuals with middle age– and elderly onset diabetes; however, elderly individuals with middle age–onset diabetes were more likely to be treated than elderly onset diabetic subjects (71.7 vs. 59.3%, $P = 0.001$). High cholesterol and its control

Table 1—*Demographic characteristics of elderly and nonelderly adults with and without diabetes, NHANES 1999–2002*

	Middle aged (40–64 years)		Elderly (≥65 years)			
	No diabetes	Diabetes	No diabetes	Middle age–onset diabetes	Elderly onset diabetes	*P* value*
n	3,391	374	2,344	272	193	
Mean age (years)	49.9 ± 0.2	53.3 ± 0.4	74.3 ± 0.2	71.7 ± 0.6	76.5 ± 0.6	<0.0001
Male sex	47.9 ± 0.9	57.2 ± 2.9	42.0 ± 1.0	43.6 ± 4.9	41.9 ± 5.2	0.821
Race/ethnicity†						
Non-Hispanic white	75.8 ± 1.7	54.1 ± 5.5	84.4 ± 2.2	70.9 ± 3.9	79.9 ± 4.0	0.0659
Non-Hispanic black	10.2 ± 1.3	17.5 ± 3.6	6.6 ± 1.1	15.6 ± 3.8	7.8 ± 2.2	0.0013
Mexican American	5.0 ± 0.8	8.3 ± 1.6	2.3 ± 0.5	4.7 ± 1.3	3.3 ± 0.9	0.0275
Education						
Greater than high school	57.5 ± 1.6	46.7 ± 3.5	40.4 ± 1.5	27.9 ± 3.2	23.0 ± 5.7	0.0311
High school or equivalent	23.9 ± 1.2	23.0 ± 2.5	28.4 ± 1.2	29.2 ± 4.4	31.1 ± 5.2	0.1725
Less than high school	18.6 ± 1.0	30.3 ± 3.3	31.2 ± 1.7	42.9 ± 3.4	45.8 ± 4.8	0.0365
Mean BMI (kg/m^2)	28.4 ± 0.2	32.3 ± 0.6	27.4 ± 0.1	30.6 ± 0.5	29.4 ± 0.7	0.136
Mean waist circumference (cm)	97.2 ± 0.5	108.3 ± 1.4	97.9 ± 0.3	106.4 ± 1.3	104.4 ± 1.3	0.271

Data are % ± SE unless otherwise indicated. **P* value for the comparison between elderly middle age– and elderly onset diabetes groups. †Prevalence for "all other" race/ethnicity category not shown.

Table 2—*Selected clinical characteristics of middle aged and elderly adults with and without diabetes, NHANES 1999–2002*

	Middle aged (40–64 years)		Elderly (≥65 years)			
	No diabetes	Diabetes	No diabetes	Middle age–onset diabetes	Elderly onset diabetes	*P* value*
n	3,391	374	2,344	272	193	
Mean fasting glucose (mg/dl)	99.8 ± 0.6	148.9 ± 5.0	105.4 ± 1.2	172.4 ± 11.1	132.3 ± 6.1	0.001
Mean A1C (%)	5.4 ± 0.02	7.7 ± 0.2	5.6 ± 0.02	7.4 ± 0.1	6.9 ± 0.2	0.011
A1C >7%	1.4 ± 0.3	55.3 ± 3.3	2.1 ± 0.4	59.9 ± 4.2	41.6 ± 4.5	0.005
A1C >8%	0.8 ± 0.2	36.7 ± 3.5	0.9 ± 0.3†	27.9 ± 4.7	20.2 ± 4.6	0.149
Mean age at diagnosis of diabetes (years)‡	—	46.7 ± 0.6	—	53.2 ± 0.7	71.8 ± 0.5	<0.001
Years since diagnosis of diabetes‡						
>10 years	—	25.4 ± 2.6	—	76.7 ± 3.8	10.9 ± 3.2	<0.0001
5–10 years	—	26.9 ± 2.8	—	17.6 ± 3.8	24.1 ± 4.7	0.3490
<5 years	—	47.7 ± 3.6	—	5.7 ± 1.8	65.0 ± 5.5	<0.0001
Glucose-lowering medication use‡						
No medication	100	18.9 ± 3.3	100	9.0 ± 2.8	22.5 ± 3.8	0.1327
Insulin use	—	9.4 ± 2.3	—	31.7 ± 4.7	6.9 ± 1.3	<0.0001
Oral medication use	—	61.4 ± 3.2	—	45.6 ± 4.2	67.5 ± 4.6	0.8319
Both insulin and oral	—	10.2 ± 2.3	—	13.7 ± 2.7	3.2 ± 1.6	0.0004
History of cardiovascular disease	5.6 ± 0.6	13.9 ± 2.6	19.6 ± 1.3	36.1 ± 4.0	34.7 ± 4.5	0.817
History of stroke	1.7 ± 0.3	5.0 ± 1.6	7.8 ± 0.8	14.0 ± 3.3	11.4 ± 2.9	0.596
History of coronary heart disease	4.3 ± 0.4	10.4 ± 2.6	14.0 ± 1.1	30.1 ± 4.4	28.2 ± 4.4	0.754
Peripheral arterial disease	2.4 ± 0.3	6.0 ± 2.0	12.0 ± 1.0	22.4 ± 6.5	18.4 ± 4.1	0.584
Peripheral neuropathy	7.9 ± 0.7	16.9 ± 2.8	21.5 ± 1.3	35.5 ± 6.1	37.1 ± 6.0	0.855
History of retinopathy‡	—	24.8 ± 3.2	—	39.4 ± 4.3	12.6 ± 3.6†	<0.0001

Data are proportions ± SE unless otherwise indicated. **P* value for the comparison between the elderly middle age–onset and elderly onset diabetes groups. †Estimate has a relative SE >30%. ‡Question was only asked in individuals with diagnosed diabetes.

followed a similar pattern, with a high prevalence in both elderly individuals with middle age–onset diabetes and individuals with elderly onset diabetes (55 vs. 45.4%, $P = 0.22$). The prevalences of treated hypercholesterolemia in these two groups were 50.4 and 39.3%, respectively ($P = 0.003$). Although the prevalence of hypertension and cholesterol treatment differed, mean levels of these risk factors were similar. In elderly individuals with middle age–onset diabetes, mean systolic blood pressure was 140.2 mmHg, and in individuals with elderly onset diabetes it was 140.6 mmHg ($P = 0.930$). A similar pattern was observed for mean cholesterol levels, with mean total cholesterol levels of 200.8 mg/dl in elderly individuals with middle age–onset diabetes and 197.0 mg/dl in individuals with elderly onset diabetes ($P = 0.558$). Smoking rates in elderly onset and middle age–onset elderly diabetic subjects were similar (10.0 vs. 7.5%, $P = 0.22$) but much lower than those in nonelderly individuals, who had a current smoking prevalence of 24% in both the diabetic and nondiabetic groups.

CONCLUSIONS— This study provides an overall picture of the characteristics of individuals with middle age–onset and elderly onset diabetes and the burden of microvascular and macrovascular disease and control of risk factors in these groups. Our overarching conclusion is that elderly individuals with middle age– and elderly onset diabetes represent distinct groups with differing burdens of disease and possibly differing treatment goals. Treatment of diabetes differed considerably between these two groups, and A1C levels were significantly higher in individuals with middle age–onset diabetes. Elderly individuals with middle age–onset diabetes were more likely to be treated for hypertension and hypercholesterolemia than elderly onset diabetic subjects; however, mean systolic blood pressure values and mean total cholesterol levels were similar in elderly individuals with middle age–onset and elderly onset diabetes, suggesting that elderly individuals may actually require less treatment to remain in control of cardiovascular risk factors.

Previous studies of diabetes in elderly individuals have not distinguished between individuals with diabetes who were diagnosed at younger ages and those with elderly onset diabetes. It has been stated that "very few older people truly have new onset diabetes" (7). Ostensibly, because there are no clear screening recommendations for diabetes in elderly individuals and because symptoms may be less recognizable or lacking, detection of new-onset diabetes in elderly individuals regardless of its presence may be uncommon. Nonetheless, because NHANES obtained fasting glucose measurements from participants, we were able to estimate the prevalence of undiagnosed diabetes among elderly individuals. We found that 6.9% of elderly individuals had undiagnosed diabetes, representing ~2.4 million individuals in the U.S. population. Few data on the actual incidence of new-onset diabetes in elderly individuals exist, and our understanding of the epidemiology and natural history of this condition is poor. The information presented here suggests that the two groups are distinct and speaks to the need to consider elderly individuals with diabetes diagnosed in middle age differently from individuals with elderly onset diabetes.

The substantial difference in age between the middle age–onset and elderly onset diabetic subjects (~5 year difference) probably reflects a "survival effect" in these cross-sectional data. That is, those individuals with middle age–onset diabetes are more likely to die at younger ages compared with individuals with elderly onset diabetes who, by definition, must be aged ≥65 years when diabetes is diagnosed. This may also explain why the burden of cardiovascular disease was similar between the groups. By definition, duration of diabetes also differed considerably in the two groups, reflected in the significantly higher prevalence of retinopathy in the middle age–onset diabetic group. In this cross-sectional study, we could not rigorously address how duration of diabetes contributed to the observed differences. Indeed, we lacked data on the timing of disease development, and we could not characterize the progression from impaired glucose tolerance to undiagnosed diabetes in this population. This is an inherent weakness in these cross-sectional survey data. The presence of a survival effect highlights the need for prospective epidemiologic studies to examine the natural history of diabetes in the elderly population. Additionally, because self-reported information was used for determination of a history of cardiovascular disease and retinopathy, we may have underestimated the burden of these conditions in this population.

Current clinical guidelines for the treatment of hypertension (Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure [JNC 7]) recommend explicitly that the same principles outlined for the general care of hypertension should be followed for older individuals. Hypertension occurs in more than two-thirds of elderly individuals, and multiple drugs are often needed to achieve recommended blood pressure goals. Nonetheless, these guidelines caution that orthostatic hypotension is a risk in individuals with diabetes and in elderly individuals, especially when multiple medications are used. The American Diabetes Association and the American Geriatrics Society additionally recommend that that blood pressure should be lowered gradually to avoid complications in elderly hypertensive patients with diabetes (8,9), but no specific recommendations have been made regarding during what period of time blood pressure should be lowered. Subgroup analyses of clinical trial data of statin therapies support lipid control in elderly individuals at high risk for cardiovascular disease (10–13), but there are limited data specifically for elderly patients with diabetes. Current diabetes treatment guidelines recommend aggressive lipid control in all patients with diabetes but do not make specific recommendations for elderly individuals.

Higher glycemic goals may also be appropriate for individuals with severe or frequent hypoglycemia, a common problem for elderly individuals. Citing the lack of clinical trial data in elderly patients, the American Diabetes Association recommends that "less stringent treatment goals" may be appropriate in elderly patients. The *Merck Manual of Geriatrics* (14) recommends a glycemic goal of A1C <7% for all elderly patients but states that "most elderly patients can be treated as aggressively as younger patients, but some require modifications based on their life expectancy, functional status, cognitive abilities, preferences, and multiple other factors."

In this study, we document a high prevalence of diabetes in the elderly population and a high rate of poor glycemic control regardless of age of diagnosis. Data and rigorous studies of new-onset diabetes in elderly subjects are needed to characterize the natural history of diabetes in the elderly population, and future researchers on diabetes in elderly individuals may need to consider stratification based on age of diabetes diagnosis.

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