Cognitive Dysfunction Is Associated With Poor Diabetes Control in Older Adults

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Abstract

OBJECTIVE—To evaluate the association between cognitive dysfunction and other barriers and glycemic control in older adults with diabetes.

RESEARCH DESIGN AND METHODS—Patients over the age of 70 years presenting to a geriatric diabetes clinic were evaluated for barriers to successful diabetes management. Patients were screened for cognitive dysfunction with the Mini Mental State Examination (MMSE) and a clock-drawing test (CDT) scored by *1*) a method validated by Mendez et al. and *2*) a modified CDT (clock in a box [CIB]). Depression was evaluated with the Geriatric Depression Scale. Interview questionnaires surveyed activities of daily living (ADLs) and instrumental ADLs (IADLs), as well as other functional disabilities.

RESULTS—Sixty patients (age 79 ± 5 years, diabetes duration 14 ± 13 years) were evaluated. Thirty-four percent of patients had low CIB (≤5), and 38% of patients had low CDT (≤13). Both CIB as well as CDT were inversely correlated with HbA_{1c}, suggesting that cognitive dysfunction is associated with poor glycemic control ($r = -0.37$, $P < 0.004$ and $r = -0.38$, $P < 0.004$, respectively). Thirty-three percent of patients had depressive symptoms with greater difficulty completing the tasks of the IADL survey (5.7 ± 1.7 vs. 4.6 ± 2.0; $P < 0.03$). These older adults with diabetes had a high incidence of functional disabilities, including hearing impairment (48%), vision impairment (53%), history of recent falls (33%), fear of falls (44%), and difficulty performing IADLs (39%).

CONCLUSIONS—Older adults with diabetes have a high risk of undiagnosed cognitive dysfunction, depression, and functional disabilities. Cognitive dysfunction in this population is associated with poor diabetes control.

Diabetes in older adults has become a major public health problem affecting an increasing number of individuals worldwide. Both older age and diabetes are independently associated with an increased risk of cognitive dys-function; the risk is even greater for older adults with diabetes (1-6). Neuropsychological tests have shown deficits in various aspects of cognitive

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

function in both young and older patients with diabetes. Deficits have been seen in areas of psychomotor efficiency, global cognition, episodic memory, semantic memory, and working memory (7,8). Abnormalities in cognitive functions mediated by frontal lobe (executive functions), including a number of complex behaviors such as problem solving, planning, organization, insight, reasoning, and attention, are noted in patients with diabetes (9-12). Considering the importance of self-management behaviors in diabetes treatment and the high complexity of diabetes treatment regimens (e.g., blood glucose testing, meal planning, medication compliance), diabetic patients with cognitive dysfunction may experience significant difficulty managing their disease. They may also have difficulty treating acute conditions associated with diabetes treatment such as hypoglycemia. Cognitive dysfunction, especially executive dys-function, can affect insight into one's behavior (13,14) and may, therefore, contribute to the patient minimizing the difficulties that he/she is experiencing. Such patients are unlikely to self-report either cognitive problems or difficulty managing their diabetes. As a result, many healthcare providers may be unaware that their patients have cognitive dysfunction.

Diabetes and cognitive dysfunction have also been associated with depression and functional impairment in elderly patients (15-21). Therefore, we hypothesize that cognitive dysfunction along with declining overall functional status and co-morbid conditions such as depression may form a barrier to achieving or maintaining good glycemic control among older adults with diabetes. While the majority of elderly patients, especially those with diabetes, are screened for cardiovascular risk factors, few of these patients are screened or evaluated for impairments in cognitive functions. We assessed unrecognized barriers to successful management of diabetes at a geriatric diabetes clinic by screening older adults over the age of 70 years for the presence of depression and functional disabilities, as well as cognitive dysfunction

RESEARCH DESIGN AND METHODS

We analyzed data collected from consecutive patients age 70 or older who were evaluated at a geriatric diabetes clinic and who underwent screening by a diabetes educator. Patients with an established diagnosis of dementia or a memory disorder, those needing an interpreter, or those with severe visual impairment (unable to complete the tests) were excluded. The study was reviewed and found to be exempt by the institutional review board. The cognitive measures, questionnaires, and tests included in this study are described in detail below.

Mini Mental State Examination

The Mini Mental State Examination (MMSE) is one of the most commonly used cognitive screening measures because it is quick and easy to administer (22,23). The MMSE includes specific questions related to attention, orientation, memory, calculation, and language. The measure's scoring is based on 30 total points, and impairment is indicated by a score of 24 or lower. While this measure is often used to screen for memory function, it has a number of psychometric limitations, such as few executive function items. While the MMSE has good specificity (96%), the sensitivity is poor (64%), suggesting that cognitive changes remain undetected in a number of individuals (24).

Clock drawing test

The clock-drawing test (CDT) is a well-known and validated measure of cognitive function that is used commonly in clinical practice due to its ease of administration (25,26). Several scoring systems have been used and standardized by investigators as a screen for cognitive dysfunction (27-30). In this test, participants are presented with two sheets of paper: one provides written instructions, the other serves as a response sheet. The instructions direct participants to draw a clock and set the time to ten minutes after eleven.

CDT Scored by Mendez method

We have used the scoring system validated by Mendez et al. (29), which uses a 20-point scale as reported. This system of scoring has been shown to be most accurate in predicting deficit in cognitive function and correlates with MMSE (31,32).

Clock-in-a-box test

The clock-in-a-box (CIB) test is a modified CDT aimed at screening cognitive dysfunction in the medical setting (10). This test was developed specifically to be a fast and reliable index of executive function. In this test, as an added step participants are asked to draw a clock in the blue box. The response sheet includes four 9.5×12.5-cm boxes, each of a different color (yellow, red, green, and blue). Each CIB clock is scored using an eight-point scale that consists of four-point working memory and four-point executive function subscores. The four features that contribute to the working memory subscore include completing the drawing in the correct square, resemblance to a clock, writing all numbers, and setting the correct time. The four features that contribute to the executive function subscore include drawing an appropriately sized clock with hands of different lengths and writing the numbers in numerical order and also evenly spaced. The total score is the sum of the memory and executive function subscores. Total score in CIB is used to assess overall cognitive function.

Geriatric depression scale

The 15-item Geriatric Depression Scale (GDS) is a well-validated tool often used to screen for depressive symptoms in older individuals (33,34). This measure is scored based on a 15-point scale, and impairment is indicated by a score of 5 or higher.

Questionnaires

Questionnaires were administered via interview by a nurse educator in a geriatric diabetes clinic to evaluate self-reported functional disabilities. These questionnaires addressed difficulty with vision, hearing, falls and fear of falls, activities of daily living (ADLs), and instrumental ADLs (IADLs). The ADL and IADL questionnaires are informant-based assessments of functional abilities. The ADL questionnaire measures functionality in five areas: bathing, toileting, grooming, dressing, and eating. The IADL questionnaire measures functionality in traveling, shopping, housework, managing finances, using the telephone, and taking medications. ADL and IADL scales are scored inversely relative to disability, such that lower scores indicate higher levels of disability.

Demographics and clinical information on diabetes

Demographic information and information pertaining to diabetes and its control was collected from the data gathered during the clinic visit. These data included age, sex, type and duration of diabetes, HbA_{1c} (A1C), self-reported history of hypoglycemia, and the type of treatment for diabetes (insulin, oral, medications, and/or lifestyle modification).

Statistical methods

Data are presented as means ± SD for continuous data and as *n* (%) for frequency data. The CDT is scored with two methods. One is the scoring method validated by Mendez (CDT) and the second one is the modified version (CIB). We estimated odds ratios (ORs) for continuous data using simple logistic regression and evaluated difference in frequency data using Fisher's exact test. We estimated Pearson or Spearman correlation coefficients depending on the bivariate distributions of continuous variables. We then estimated simple linear regression models predicting A1C with variables of interest. Finally, we estimated multivariate models predicting A1C controlling for variables of interest.

Subjects then were divided into two groups based on performance of CDT and CIB separated at the mean value of the total test scores. Those participants with a CIB total score of ≤5 were assigned to the CIB low group, whereas those with a CIB total score of ≥6 were assigned to the CIB high group. Similarly, participants with a CDT score of ≤13 were assigned to the CDT low group, whereas those with a CDT score of ≥14 were assigned to the CDT high group. Data were analyzed using SAS, version 8.02 (SAS Institute, Cary, NC). A1C provides an estimate of glycemic control for the previous 2–3 months. A1C was measured at the Joslin Diabetes Center using the high-performance liquid chromatography ion capture method (reference range 4.0–6.0%; Tosoh Medics, San Francisco, CA).

RESULT

Sixty consecutive patients over the age of 70 years with type 2 diabetes seen at a geriatric diabetes clinic were evaluated. The mean age of the population was 79 ± 5 years (range 70–93); the mean duration of diabetes was 14 ± 13 years (1-55), and the mean A1C was $7.9 \pm 1.4\%$. The higher proportion of the study population was female (female-to-male ratio 58:42), Caucasian (82%), and college educated (53%), with 92% having at least some high school education. Sixty-eight percent of patients lived with their spouse or other family members, representing a relatively well-supported population seen at this tertiary care specialized institution. The characteristics of the study population and the treatment modalities utilized for glycemic control are listed in Table 1.

We observed significant functional disability in our patient sample. Forty-eight percent of the patients had hearing impairments, 53% had vision impairments, 33% had a history of recent falls, and 44% were afraid of falling. Although a majority (95%) of the patients were able to perform ADLs independently, only 39% could carry out IADLs independently, suggesting the need for significant support from caregivers.

All patients were evaluated for cognitive dysfunction with the MMSE, CDT, and CIB tests and for depression with the GDS test described in the RESEARCH DESIGN AND METHODS section. Two patients were unable to perform CDT/CIB due to language barrier, although they were able to complete tasks on other measures. The mean CIB score for the population was 6 and mean CDT score was 14. Of all the patients, 35% were below the mean CIB score, and 38% were below the mean CDT score. Twelve percent of patients had a MMSE score below 24. MMSE score correlated with CIB as well as CDT scores ($r = 0.45$, $P < 0.0004$ and $r = 0.33$, $P < 0.01$, respectively). Next, we evaluated the relationship between cognitive dysfunction and glycemic control as measured by A1C levels. An inverse correlation was observed between CIB and A1C ($r = -0.37$, $P < 0.004$), as well as CDT and A1C ($r = -0.38$, $P < 0.003$); however, MMSE, demographic, depression, and other variables did not correlate with A1C. Simple linear regression models confirmed both CIB ($R^2 = 0.139$, $P = 0.004$) and CDT ($R^2 = 0.144$, $P = 0.003$) to be predictive for glycemic control. In a multivariate analyses, controlling for variables of interest including age, sex, living status, BMI, duration of diabetes, depression, MMSE, education, and other comorbidities, cognitive dysfunction measured by either CIB or CDT was the only predictor of poor glycemic control. Patients with high or low MMSE scores did not differ in diabetes control as seen by A1C level (8.44 ± 1.66 vs. $7.81 \pm 1.32\%$; OR 1.36 [95% CI 0.82–2.254]). However, patients with cognitive dysfunction had a higher A1C compared with patients without cognitive dysfunction; A1C in high versus low CIB was 8.7 ± 1.4 vs. $7.5 \pm 1.2\%$, respectively (2.016 [1.258–3.229]; $P < 0.003$), and A1C in high versus low CDT was 8.4 ± 1.6 vs. $7.6 \pm 1.1\%$ ($P < 0.05$) (Fig. 1).

Thirty-three percent of patients had depressive symptoms as suggested by GDS scores ≥5. No correlation was observed between CIB, CDT, or MMSE scores and depression; however, patients with depression had greater difficulty completing the tasks of the IADLs (5.7 vs. 4.6;

$P < 0.03$; 0.720 ([0.531–0.976]). Glycemic control was not associated with the presence of depression as assessed by the GDS.

We next evaluated the group of patients with low versus high CIB scores (Table 1). We did not observe significant differences in age, sex, and duration of diabetes in patients with or without cognitive dysfunction (low versus high CIB). However, patients with a low CIB score had a lower BMI (26 vs. 30; 0.883 [0.786–0.992]; $P < 0.03$) and were more likely to be on insulin treatment ($P = 0.05$). There was a higher incidence of weight loss, hypoglycemic episodes, and difficulty performing IADLs independently in patients with cognitive dysfunction; however, the differences did not reach statistical significance. More than a third (35%) of patients with a low CIB score were living alone, which puts this vulnerable population at higher risk of complications due to the multiple barriers they face.

CONCLUSIONS

Elderly patients with diabetes have an increased risk of developing cognitive problems. Our study is the first to evaluate cognitive dysfunction in older adults with diabetes and to correlate it with diabetes control. One-third of the study population had cognitive dysfunction as described by the CIB, and its presence was associated with poor diabetes control.

Cognitive functions that enable complex behaviors are particularly important for patients with diabetes. Ever since landmark trials demonstrated a decline in diabetes-related complications following tight glycemic control (35,36), diabetes treatment regimens have become more complex in an effort to achieve this goal. However, older patients with diabetes and concomitant cognitive dysfunction may be unable to follow complicated regimens (e.g., multiple daily insulin injections with or without a sliding scale, multiple oral medications, complex dietary regimen). These patients may be at increased risk of treatment complications (e.g., omission of meals leading to hypoglycemia or incorrect dose or timing of insulin injections and/or oral medications). Thus cognitive dysfunction is an important comorbidity that needs to be identified in older adults with diabetes for goal adjustment and/or individualization and simplification of treatment plans. To that end, the fact that 35% of our study patients with cognitive dysfunction were living alone is worrisome. Patients living alone typically do not have the benefit of interacting with, or being closely observed by, family members or friends over an extended period of time. As a result, health care providers must rely on self-report of complications such as hypoglycemia and other health problems with these patients, which may be underreported.

In our study, we have utilized easily administered tools to assess cognitive function. The CIB was designed specifically to assess working memory and executive function components of cognitive function. As this test has not been fully validated yet, we have further confirmed our results using a validated CDT. CIB and CDT were superior at identifying patients with cognitive dysfunction, compared with MMSE, a more widely used tool to evaluate cognitive dysfunction. MMSE has been reported to have low sensitivity in detecting subtle cognitive dysfunction. In an analysis of multiple longitudinal studies in patients with diabetes who were at higher risk of cognitive dysfunction, MMSE proved less sensitive than other psychometric tests (37). However, with only seven patients with low MMSE score in this study, there is a higher risk of sampling error. Performance on the CIB is related to performance on standardized measures of memory and executive functions such as Trail Making B, Hopkins Verbal Learning, and verbal fluency tests (10). CIB was more sensitive in predicting poor glycemic control than CDT. Subtle changes in cognition, especially executive functions, are difficult to detect during a short office visit, and tools such as CIB or CDT can be used to identify vulnerable individuals with cognitive dysfunction quickly.

Patients with diabetes are twice as likely to experience depression when compared with individuals without diabetes (38). In our study of older patients with diabetes, 32% of men and 34% of women reported depressive symptoms. Depression in patients with diabetes is independently associated with increased healthcare use and expenditures (39). Although diabetes self-management could be affected by depression, we did not find an association between the presence of depression and glycemic control. However, depression was associated with decreased ability to perform IADLs, which may add to the functional disability and dependence observed in older patients with diabetes.

The high prevalence of functional disabilities observed in our study population is consistent with prior reports. Diabetes has been associated with increased incidence of functional disabilities (11,18) and increased risk of falls and fractures (40). Cognitive functions, especially executive dysfunction, has been reported to correlate with inability to perform lower-extremity tasks (21). These data offer insight into why older adults with diabetes are at higher risk of falls (42). Thirty-three percent of the study patients had a history of falls compared with a general population of older adults without diabetes (42). Falls and fear of falls, possibly indicating balance and gait disturbance or muscle deconditioning, can increase the risk of injuries in this vulnerable population. Forty-eight percent of the study population had hearing impairments compared with 38% in the general population age >65 years, and 53% had vision impairments compared with 17% in the national population of older adults (43). Hearing and vision impairments can also add to functional decline and increased morbidity. While some of these disabilities can be improved (e.g., physical therapy for deconditioning and gait training), it is imperative that clinicians screen for these barriers in older patients with diabetes.

Our study was conducted at a tertiary care specialty setting. Patients in this setting tend to be highly motivated, educated, and have excellent support systems. We presume that the prevalence of barriers to diabetes control will be even higher in community settings, and these barriers may remain undiagnosed. Adverse outcomes due to unrecognized barriers would also be more prevalent in these settings.

In summary, this study identifies the high prevalence of cognitive dysfunction, depression, and functional disabilities among the elderly with diabetes and draws attention to various challenges in their management. First, all older patients with diabetes need to be evaluated for barriers to safe and effective diabetes control. Screening for subtle cognitive dysfunction is important when complicated treatment regimens are used. Second, goals for glycemic control may need to be adjusted and diabetes treatment regimens simplified. Third, older patients with diabetes and executive dysfunction may need special education and skills to manage their disease. Family members who live with patients or who are caregivers from a distance may benefit from education and support to enable them to effectively help these older patients. Lastly, it is essential to formulate diabetes treatment regimens, which are least likely to cause hypoglycemia. The risk versus benefit ratio of glycemic control needs to be frequently assessed among elderly with cognitive dysfunction to achieve the tightest possible control with the lowest possible risk of hypoglycemia.

Acknowledgments

Abbreviations

ADL, activity of daily living; CDT, clock-drawing test; CIB, clock in a box; GDS, Geriatric Depression Scale; IADL, instrumental ADL; MMSE, Mini Mental State Examination.

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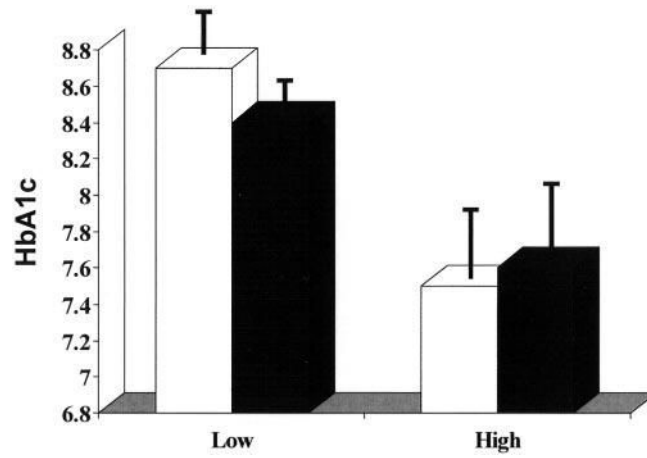
Figure 1.
Patients with cognitive dysfunction (CIB ≤5 or CDT ≤13) had a higher A1C, indicating poorer glycemic control compared with patients without cognitive dysfunction (P < 0.003 with CIB and P < 0.05 with CDT).□, CIB; ■, CDT.

Table 1

Demographic and health characteristics of study population and variables separated by low versus high CIB score

	All patients	CIB high	CIB low
n	58	38	20
Age (years)	79 ± 5	77.73 ± 5.3	80.3 ± 4.5
Duration of diabetes (years)	14 ± 13	13.07 ± 11.6	17.45 ± 16.2
Average A1C (%)	7.9 ± 1.4	7.5 ± 1.17	8.725 ± 1.43
BMI (kg/m^2) [*]	28 ± 6	29.70 ± 5.09	26.45 ± 5.54
Ethnicity (%)			
Caucasians	82	94.7	60
African Americans	13	2.6	30
Hispanics	5	2.6	10
Education (%)			
Elementary	5	66	32
Middle	3	0	11
High school	39	34	47
College	53	0	11
Living status (%)			
Alone	30	26	35
With spouse	50	55	40
With others	20	18	25
Smoking (%)			
Current	5	5	5
Previous history	45	53	30
Treatment modality (%)			
Lifestyle modification	3	5	0
Oral medications only	58	66	45
Insulin only	15	11	20
Oral medications + insulin	23	18	35
Comorbidities (%)			
Hypertension	93	92	95
Hypercholesteremia	77	84	65
Coronary artery disease	37	45	20
Cardiovascular disease	17	18	15
Functional barriers (%)			
Hearing impairment	48	55	35
Vision impairment	53	38	65
History of recent falls	33	37	30
Fear of falling	44	39	55
Difficulty performing IADLs	39	47	25
Weight loss	18	11	30
Hypoglycemic episodes	48	39	60

[*] Statistically significant.