Executive cognitive impairment detected by simple bedside testing is associated with poor glycaemic control in type 2 diabetes

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Aims. Cognitive impairment in people with type 2 diabetes is a barrier to successful disease management. We sought to determine whether impaired executive function as detected by a battery of simple bedside cognitive tests of executive function was associated with inadequate glycaemic control.

Methods. People with type 2 diabetes attending a tertiary referral diabetic clinic who consented to participate in the study underwent a brief battery of cognitive testing (the Bedside Executive Screening Test) designed to detect executive function impairment. Glycaemic control was determined using blood glycated haemoglobin levels (HBA_{1c}). Inadequate glycaemic control was defined as $HBA_{1c} \geq 7\%$.

Results. Executive function impairment was detected in 51 (52%) of the 98 study participants. The presence of executive function impairment was significantly associated with poor glycaemic control ($HBA_{1c} \geq 7\%$) (odds ratio 4.9, 95% confidence interval 1.3 - 18.8, $p=0.019$). There were no significant differences between patients with and without executive function impairment with regard to age, target organ damage, patient reported adherence, and hypoglycaemic therapy. Patients with a lower level of education were more likely to demonstrate executive impairment when glycaemic control was poor ($p=0.013$).

Conclusions. Executive function impairment is common in a population of people with difficult-to-manage type 2 diabetes. The presence of executive impairment is significantly associated with poor glycaemic control.

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Conventional management of type 2 diabetes relies heavily on the principles of self-management. This is in essence a series of complex goal-directed behaviours required for lifestyle and behavioural changes as well as adherence to pharmacological interventions aimed at managing glycaemic control, hypertension, lipid profiles, weight and physical activity. Successful disease management is dependent on the patient's ability to execute these interventions and maintain lifelong adherence. Not only do people with type 2 diabetes have a greater rate of decline in cognitive functioning and risk of future dementia than people without diabetes,[1,2] but the cognitive impairment is associated with poor diabetes control.[3,4]

The executive functioning domain of cognition is important in allowing the development of adaptive strategies and the ability of an individual to modify his/her behaviour in response to dynamic task requirements.[5] Impairment of executive function has been clinically linked with functional impairment, poor medication adherence, increased level of care needed and even patient resistance to care.[6-8] Executive impairment divorces ability from implementation.[5] Type 2 diabetes has been shown to be associated with impairment in executive cognitive functioning.[6,9,10] This is attributed to frontal-subcortical dysfunction due to microvascular disease.[5,10]

We sought to determine whether executive impairment as detected by a simple battery of beside executive function tests was associated with inadequate glycaemic control as defined by an HBA_{1c} level $\geq 7\%$.

Patients and methods

People with type 2 diabetes attending the tertiary referral Diabetic Clinic at Groote Schuur Hospital, Cape Town, were invited to participate in the study during their usual clinic visits between 1 March 2006 and 31 June 2006. Groote Schuur Hospital is a university teaching hospital serving an open population of approximately 2.9 million persons. The clinic provides care for people with diabetes from lower socio-economic income groups (more affluent patients with health insurance tend to seek medical care in the private sector), with poor disease control and/or established target organ damage. Study exclusion criteria included poor fluency in the English language, visual or hearing impairment, current management with an antidepressant, and/or precognitive evaluation blood glucose <4 mmol/l or >15 mmol/l on the day of assessment.

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Cognitive testing was performed using a battery we termed the Bedside Executive Screening Test (BEST). This comprised five parts:

- three item registration

- three item delayed recall test

- executive clock drawing task part 1 (CLOX1): *'draw me a clock that says 1:45. Put the numbers on the face so that a child could read them'*[11]

- verbal fluency test: *'name as many animals with 4 legs as you can think of in 1 minute'*

- problem solving task: *'I have 18 books that I need to put on 2 shelves. One of the shelves must have twice as many books on it as the other shelf. How many books must I put on each shelf?'*

The latter three cognitive tests draw mainly on the cognitive domain of executive functioning.[6,7] Abnormal tests were defined as:

- CLOX1 score of <10[11]

- naming ≤12 animals (or ≤11 if patients had completed fewer than 9 years of education)[12]

- inability to solve the problem correctly.

An assessment of executive impairment was made if patients had abnormal results for at least two of the three tests of executive functioning. The cognitive tests were administered according to a standardised proforma by either the attending clinician or a research nursing assistant.

Clinical, demographic and laboratory characteristics were recorded at the time of assessment and included gender, age, level of education (in completed years), laboratory blood glucose and glycated haemoglobin level on the day of assessment, the presence or absence of microvascular (retinopathy, nephropathy, neuropathy) and macrovascular (ischaemic heart disease, peripheral vascular disease) complications, patient-reported dietary and medication adherence, and the various medications the patient reported using.

All microvascular and macrovascular complications were defined according to our clinic protocol. A composite score of the three abovementioned microvascular and two abovementioned macrovascular complications was created.

Student's *t*-test was used to determine the statistical difference between the means of age, years of education and total number of target organs damaged. The chi-square test was used to assess the statistical difference between dietary and medication adherence as well as the difference in drug use between patients with and without executive impairment. Fisher's exact test was used to assess the statistical differences in diabetic control between those with and without executive impairment. The institutional Ethics Committee approved the study protocol and all study subjects gave written informed consent.

Results

Of the one hundred and seven patients recruited, 98 consented to participation in the study. Women comprised 61 patients (62%). The mean age was 57.7 years (standard deviation (SD) 10.4) (range 31 - 85 years), and the mean education level was 8.2 years (SD 2.5) (range 3 - 16 years). Executive function impairment was present in 51 (52%) of the participants. For the clock drawing task (CLOX1) the mean score was 11.0 (SD 3.2) (range 2 - 15), with 22 (22%) of patients scoring below 10 (Fig. 1). The mean verbal fluency score was 10.3 (SD 3.2) (range 4 - 27), with 70 patients (71%) naming fewer than 12 animals. Only 46 patients (47%) answered the book problem correctly, with 28 patients giving the answer as '9 and 9'.
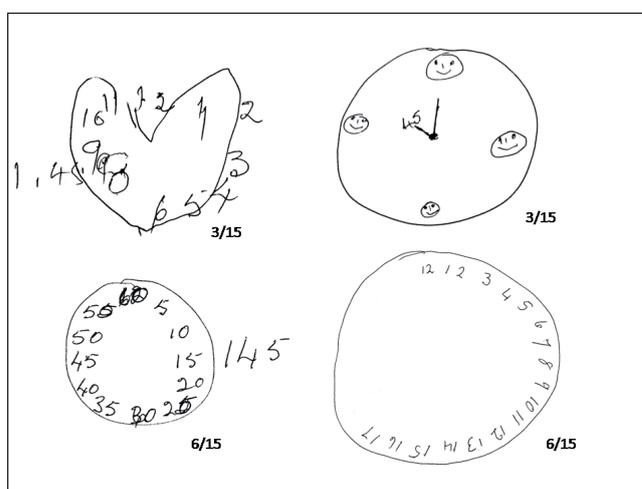

Fig. 1. Examples of abnormal clocks drawn by study participants demonstrating executive cognitive impairment. CLOX score is indicated.

Table I shows the demographic characteristics, diabetic control, reported adherence, target organ damage and drug usage differences between the study patients with and without executive impairment.

Patients with executive impairment were more likely to have poor diabetic control (odds ratio 4.9, 95% confidence interval 1.3 - 18.8).

Discussion

Our study population, in keeping with many other diabetes clinics throughout the world, comprised predominantly people with type 2 diabetes with inadequate glycaemic control and/or target organ damage. Education is shown to affect executive function.[12] In our study patients with lower levels of education appeared more vulnerable to executive impairment when glycaemic control was inadequate.

The achievement of individualised glycaemic targets is challenging for people with diabetes.[13] The observation that the

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Table I. Differences in demographic characteristics, diabetic control, reported adherence, target organ damage and drug usage between patients with and without executive impairment

	Executive impairment		
	Absent (*N*=47)	Present (*N*=51)	
Age (mean±SD)	56.2±10.0	59±10.7	NS
Years of education (mean±SD)			
HBA_{1c} <7.0%	9.8±3.3	8.7±1.2	NS
HBA_{1c} ≥7.0%	9.5±2.9	8.0±2.1	*p*=0.013
Diabetic control (*N* (%))			
HBA_{1c} <7.0%	11 (23%)	3 (6%)	*p*=0.019
HBA_{1c} ≥7.0%	36 (77%)	48 (94%)	
Patient reported adherence (*N* (%))			
Dietary	20 (43%)	27 (53%)*	NS
Medication	36 (77%)	36 (71%)	NS
Mean No. of target organs damaged (±SD)	1.4±1.3	1.7±1.2	NS
Drugs used (*N* (%))			
Metformin	32 (68%)	32 (63%)	NS
Sulphonylureas	18 (38%)	16 (31%)	NS
Insulin	37 (79%)	39 (76%)	NS
Aspirin	36 (77%)	32 (63%)	NS
Statin	18 (38%)	17 (33%)	NS
ACE inhibitors	36 (77%)	28 (71%)	*p*=0.041

*In 2 patients dietary adherence was unknown.
NS = not significant.

presence of executive cognitive impairment was significantly associated with poor glycaemic control in this small study was therefore notable and potentially adds another dimension to the already complex interaction between health provider and patient. Indeed, people with executive functioning deficits as detected by cognitive testing may require alternative management strategies to enhance disease control.

Traditional bedside/clinic cognitive testing has used the Mini Mental State Examination, which does not adequately test for executive cognitive impairment, with poor sensitivity, especially in early disease.[14] Formal batteries of neuropsychological tests are time consuming (taking up to 3 hours to administer) and may not be available or practical in routine clinical practice. Even a validated test such as the Executive Interview takes 15 minutes to administer, too long for the busy diabetic clinic.[15] Our bedside battery takes 5 minutes or less to administer and requires minimal training beyond the scoring of the clock drawing task (CLOX1).[11]

Clinicians are largely unaware that executive impairment may occur frequently in a variety of medical conditions, including diabetes.[6] The findings of this study should be repeated in a larger study and may well provide impetus to perform a brief cognitive screening battery routinely – we propose the use of a battery such as ours.

Specific strategies required to improve control in people with type 2 diabetes and executive impairment remain to be determined, but awareness and increased recognition of executive impairment is currently the greatest clinical challenge.

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