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ORIGINAL ARTICLE

Evaluation of glycemic control in patients with type 2 diabetes mellitus in Chinese communities: a cross-sectional study

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Abstract This study aimed to evaluate the glycemic levels in Chinese patients with type 2 diabetes mellitus (T2DM) and to explore the factors related to the results of glycemic control. A total of 2454 T2DM patients from 11 communities were examined for glycosylated hemoglobin levels and glycemic control options. Potential factors related to the results of glycemic control were analyzed using logistic regression. Of all the patients, 55.3 % achieved the glycemic control target of HbA1c < 7 %. Multivariate analysis showed that male sex (OR 1.345, 95 % CI 1.022–1.769; $P = 0.034$), higher levels of fasting blood glucose (OR 1.954, 95 % CI 1.778–2.147; $P < 0.001$), and low-density lipoprotein cholesterol (OR 1.181, 95 % CI 1.020–1.367; $P = 0.026$) were significantly associated with poor glycemic control. The complexity of antidiabetics was also associated with poor glycemic control ($P < 0.05$). Compared to diet and exercise, insulin injection was most strongly associated with poor glycemic control (OR 6.210, 95 % CI 4.054–9.514; $P < 0.001$). Male patients with higher levels of total cholesterol, lower levels of high-density lipoprotein cholesterol, or longer diabetic durations showed poor glycemic control, which was not found in female patients. Glycemic control was not satisfactory in T2DM patients of Nanjing communities. Various factors are associated with poor results of glycemic control.

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Introduction

The estimated prevalence of diabetes among Chinese adults is 11.6 %, and the prevalence of prediabetes is 50.1 % [1]. With the rapid growth of diabetes prevalence in China, the burden on health care is also increasing rapidly. Evidences have shown that the community-based management of diabetes was more effective in reducing the disease-related health problems [2, 3]. Therefore, an appropriate management model for diabetes care in communities is the key for the prevention and control of diabetes.

According to the guidelines for good glycemic control, the glycosylated hemoglobin (HbA1c) level should be controlled at a level of <7 % for most patients with type 2 diabetes mellitus (T2DM) [4–6]. Consistently, several trials in T2DM patients have also shown that good glycemic control provided more benefits in reducing microvascular and macrovascular complications [7, 8]. However, there are still a high percentage of patients failing to achieve the guideline-recommended glycemic targets, which causes significant morbidity and mortality with heavy economic burden [9]. Unfortunately, merely 25.8 % of Chinese diabetic patients received medical care, of which only 39.7 % had satisfactory glycemic control [1].

This study aimed to evaluate the status of glycemic control in Chinese T2DM patients and to analyze the potential associated factors by comparing patients with

HbA1c < 7 % and those with HbA1c ≥ 7 %. Understanding the contributing factors of poor glycemic control may help to improve the diabetes management and facilitate better care of T2DM patients in Chinese communities.

Materials and methods

Patients

This was a cross-sectional study using data from a Diabetes Community Management Program. From May 2011 to September 2013, 2454 patients diagnosed with T2DM according to the 1999 WHO criteria were recruited from 11 community healthcare centers in Nanjing, China. This study was approved by the Institutional Review Board of Jiangsu Province Institute of Geriatrics. Informed consent was obtained from each patient.

A database was established using a Web site-based registry system (www.chinasdtm.com). All patients received instructions of lifestyle modification including diet and exercise, oral antidiabetics, and/or insulin. Exclusion criteria were type 1 diabetes or secondary diabetes (including diseases of the exocrine pancreas, endocrinopathies, infection or drug-induced); participation in other clinical trials; life expectancy $\leq$2 years; cognitive impairment or unable to complete the questionnaires; incapability to complete the regular follow-up. Data of patients, who provided the details of HbA1c in the past 3 months before enrolled, were extracted and analyzed in the study.

Data collection

Well-trained investigators interviewed the patients using a standard questionnaire. The following data were collected and entered into the Web-based database: demographic data (age, sex, education level, smoking or drinking history, family history of diabetes mellitus), diabetes duration, body mass index (BMI), waist circumference, blood pressure, medications (antidiabetics, antihypertensives, lipid-lowering drugs, antiplatelets), and diabetes complications. In addition, the results of laboratory testing and clinical examination in the 3 months prior to the inclusion were collected, including HbA1c, fasting blood glucose or postprandial blood glucose (FBG/PBG), urinary albumin/creatinine ratio, lipid profiles, serum creatinine, uric acid, ankle-brachial index, and vibration perception threshold. If the patients did not have available laboratory testing results, additional examinations were performed. All data were reported and updated on the Internet once the information was available.

Statistical analysis

The descriptive analysis of demographic and clinical data was performed for the overall population and the two subgroups defined by the HbA1c level (<7 vs. $\geq$7 %). The continuous data were presented as mean $\pm$ standard deviation (SD) or median with interquartile range (IQR).

Comparisons between the two groups were made using Student's *t* tests or Chi-square tests for data with normal distribution or using Mann–Whitney *U* tests for data with skewed distribution. The variables that were significant in the univariate analysis were entered into the multivariate analysis with HbA1c $\geq$ 7 % as the dependent variable. The logistic regression model was used to evaluate the associations. Odds ratios (ORs) and their 95 % confidence intervals (CIs) were calculated. A two-sided *P* value of <0.05 was considered to be statistically significant. All analyses were performed using SPSS software version 15.0 (SPSS, Chicago, IL, USA).

Results

Basic information

A total of 3202 patients with T2DM participated in the Diabetes Community Management Program, of which 2454 (76.6 %) patients were included in this study. The patient characteristics are given in Table 1. The mean age of the patients was 65.2 $\pm$ 10.0 years, and 64.6 % were men. The median (IQR) diabetes duration was 47 (14–124) months.

Of 2454 participants, 1356 (55.3 %) achieved the HbA1c control goal of <7 % and 1098 (44.7 %) did not (Table 1). The patients with poor glycemic control were more likely to be male, have less education, have smoking or drinking histories, have longer diabetes duration compared to those with good glycemic control ($P < 0.05$). Poorer FBR and PBR control, worse clinical measures including BMI, waist circumference, lipid profile, blood pressure and serum creatinine, and more complex antidiabetic drugs were found in the patients with poor glycemic control ($P < 0.05$). No significant differences were observed in age, family history of diabetes mellitus, uric acid, macrovascular complications, estimated glomerular filtration rate, and vibration perception threshold between the two groups ($P > 0.05$).

Multivariate analysis

The significant variables in the univariate analysis were entered into the multivariate analysis using the logistic regression model. A total of 1558 patients (63.5 %) with all

Table 1 Patient characteristics

Variables	HbA1c < 7 % (*n* = 1356)	HbA1c ≥ 7 % (*n* = 1098)	*P* value
Demographic			
Age [mean ± SD (years)]	65.5 ± 9.9	64.8 ± 10.1	0.068
Sex, female [*n* (%)]	516 (38.1)	352 (32.1)	**0.002**
Education, ≤9 years [*n* (%)]	525 (38.7)	476 (43.4)	**0.020**
Current smoking [*n* (%)]	154 (11.4)	177 (16.1)	**0.001**
Current drinking [*n* (%)]	105 (7.7)	111 (10.1)	**0.040**
Hypertension [*n* (%)]	867 (63.9)	676 (61.6)	0.227
Family history of diabetes mellitus [*n* (%)]	373 (36.8)	307 (40.2)	0.144
Diabetes duration [median (IQR) (months)]	42 (13–105)	64 (15–145)	**<0.001**
Laboratory test (mean ± SD)			
HbA1c at first visit (%)	6.1 ± 0.5	8.4 ± 1.5	**<0.001**
Systolic BP (mmHg)	128.8 (14.3)	131.0 (15.1)	<0.001
Diastolic BP (mmHg)	76.6 (9.0)	77.9 (9.4)	0.003
FBG (mmol/L)	6.3 ± 1.2	8.5 ± 2.7	<0.001
PBG (mmol/L)	9.0 ± 2.5	12.3 ± 4.2	**<0.001**
BMI (kg/m^2)	24.5 ± 3.4	25.2 ± 3.2	**<0.001**
WC (cm)	88.0 ± 9.2	89.8 ± 9.0	**<0.001**
LDL-c (mmol/L)	2.6 ± 0.9	2.7 ± 0.9	**0.001**
HDL-c (mmol/L)	1.3 ± 0.4	1.2 ± 0.4	**<0.001**
TC (mmol/L)	4.7 ± 1.1	4.8 ± 1.2	**0.001**
TG (mmol/L)	1.6 ± 1.1	1.9 ± 1.8	**<0.001**
Scr (μmmol/L)	77.2 ± 27.5	79.7 ± 25.3	**0.031**
UA (μmmol/L)	293.1 ± 84.1	287.9 ± 92.6	0.224
Macrovascular complications			
Coronary heart disease, [*n* (%)]	121 (19.4)	86 (17.7)	0.472
ABI (mean ± SD)	0.9 ± 0.3	0.9 ± 0.4	0.063
Microvascular complication			
eGFR (mean ± SD)	89.1 ± 31.9	90.7 ± 34.9	0.284
ACR ≥ 30 mg/g [*n* (%)]	125 (25.1)	138 (33.7)	**0.005**
VPT (mean ± SD)	14.6 ± 8.5	15.7 ± 8.6	0.292
Treatment [*n* (%)]			
Diet and exercise alone	453 (33.4)	127 (11.6)	<0.001
1 OAD alone	425 (31.3)	263 (24.0)	
2 OADs alone	313 (23.1)	316 (28.8)	
≥3OADs alone	42 (3.1)	57 (5.2)	
Insulin injection	123 (9.1)	335 (30.5)	
Antihypertensive agents use	725 (53.5)	596 (54.3)	0.687
Lipid-lowering agents use	179 (13.2)	173 (15.8)	0.073
Antiplatelets use	394 (29.1)	346 (31.5)	0.187

Bold numbers are statistically significant

FBG fasting blood glucose, *PBG* postprandial blood glucose, *ABI* ankle-brachial index, *eGFR* estimated glomerular filtration rate, *ACR* urinary albumin/creatinine ratio, *VPT* vibration perception threshold, *BMI* body mass index, *WC* waist circumference, *LDL-c* low-density lipoprotein cholesterol, *HDL-c* high-density lipoprotein cholesterol, *TC* total cholesterol, *TG* triglycerides, *BP* blood pressure, *Scr* serum creatinine, *UA* serum uric acid, *OAD* oral antidiabetes drug

the parameters available were included in the multivariate analysis. The results showed that male sex (OR 1.345, 95 % CI 1.022–1.769; $P = 0.034$) and higher levels of FBG (OR 1.954, 95 % CI 1.778–2.147; $P < 0.001$) and LDL-c (OR 1.181, 95 % CI 1.020–1.367; $P = 0.026$) were significantly associated with poor glycemic control (Table 2). In addition, the complexity of antidiabetics was also associated with poor glycemic control ($P < 0.05$).

Table 2 Multivariate analysis of the factors related to poor glycemic control using the logistic regression model

Variable	OR	95 % CI	*P* value
Male (yes/no)	1.345	1.022–1.769	**0.034**
FBG (mmol/L)	1.954	1.778–2.147	**<0.001**
LDL-c (mmol/L)	1.181	1.020–1.367	**0.026**
Treatment			
Diet and exercise alone	1.000		
1 OAD alone	1.736	1.207–2.496	**0.003**
2 OADs alone	2.061	1.427–2.7975	**<0.001**
≥3 OADs alone	2.323	1.243–4.343	**0.008**
Injection of insulin	6.210	4.054–9.514	**<0.001**

Bold numbers are statistically significant

FBG fasting blood glucose, *BMI* body mass index, *WC* waist circumference, *LDL-c* low-density lipoprotein cholesterol, *TG* triglycerides, *BP* blood pressure, *OAD* oral antidiabetes drug

Compared to the treatment of the diet and exercise, the OR value increased along with the increase in antidiabetics number. Insulin injection was most strongly associated with poor glycemic control (OR 6.210, 95 % CI 4.054–9.514; $P < 0.001$).

Sex differences in glycemic control

The glycemic control rates were 59.5 and 53.0 % in female and male patients, respectively ($P = 0.020$). We analyzed the related factors about the poor glycemic control in two groups (Table 3). Higher levels of FBG and insulin injection were associated with poor glycemic control in both male and female patients ($P < 0.05$). However, male patients with higher levels of total cholesterol, lower levels of HDL-c, or longer diabetes duration did not have good glycemic control, which was not found in the female patients.

Table 3 Related factors of poor glycemic control in the different sex groups

Factors	Multivariate analysis		
	OR	95 % CI	*P* value
Model 1 for male			
Diabetes duration, months	1.002	1.000–1.005	0.024
TC (mmol/L)	1.301	1.075–1.573	0.007
HDL-c (mmol/L)	0.533	0.301–0.942	0.030
FBG (mmol/L)	1.824	1.604–2.075	<0.001
Treatment, *n* (%)			
Diet and exercise alone	1.000		
1 OAD alone	1.464	0.858–2.495	0.162
2 OADs alone	1.496	1.004–2.231	0.048
≥3OADs alone	1.519	0.642–3.596	0.341
Insulin injection	5.031	3.101–8.160	<0.001
Model 2 for female			
FBG (mmol/L)	2.211	1.899–2.574	<0.001
Treatment, *n* (%)			
Diet and exercise alone	1.000		
1 OAD alone	1.850	1.085–3.155	0.024
2 OADs alone	2.164	1.268–3.696	0.005
≥3OADs alone	3.384	1.209–9.471	0.020
Insulin injection	3.019	1.854–4.913	<0.001

FBG fasting blood glucose, *HDL-c* high-density lipoprotein cholesterol, *TC* total cholesterol, *OAD* oral antidiabetes drug

Discussion

The present study evaluated the status of glycemic control and the possible factors associated with poor glycemic control in 11 communities of Nanjing. Our study showed that nearly half of the patients with T2DM in these communities did not achieve the target of HbA1c control, and their FBG, PBG, BMI, LDL-c, total cholesterol, and systolic blood pressure were also not well controlled.

A national cross-sectional survey suggested that up to 113.9 million Chinese adults might have diabetes and 493.4 million have prediabetes, indicating that diabetes is a major public health problem in China [1]. In the present study, age was not found to be associated with the glycemic control results, which was inconsistent with some other studies [10, 11]. Meanwhile, younger patients were more likely to have an HbA1c ≥ 7 % than older ones [10, 11]. Patients with different ages may be required for different management standards. A near-normal glycemic target (<0.5 %) may be considered for relatively young patients with a long life expectancy, but may be not adequate for older patients with high risks of hypoglycemic episodes, cardiovascular and cerebrovascular diseases [12, 13].

We found that gender was significantly associated with glycemic control, and women were more likely to achieve the glycemic control target. This may be due to the differences in hormone levels, body fat distribution, and compliance between men and women. The long-term hormone therapy in postmenopausal women was associated with better adipocytokine profiles and healthier distribution and amount of body fat. It has been shown that fasting glucose and glycosylated hemoglobin levels were 5 and 3 % lower, respectively, in hormone therapy group than in control group [14]. We found that the different factors were related to the poor glycemic control in male and female patients. Total cholesterol and HDL-c levels were significantly associated with glycemic control in male patients, but not in female patients. Therefore, we speculate that strengthening the management of lipid profiles, especially in male patients, might improve the clinical outcomes.

Our study indicated that merely 14.3 % of the enrolled patients were on lipid-lowering agents. LDL-c was significantly associated with glycemic control. Some studies reported that fewer diabetic patients with high LDL-c received adequate lipid-lowering therapy [15, 16]. Even if the patients received the statin treatments, most of them still had persistent dyslipidemia and remained at a high risk of cardiovascular diseases [17]. Moreover, poor lipid control has been shown to be associated with lack of diet restriction [15]. Therefore, blood lipid profile is an important aspect in the management of diabetes.

Our study showed that the complexity of glucose-lowering regimens was associated with a reduced possibility of achieving the target of HbA1c < 7 %. Previous studies also found the association between HbA1c and complexity of treatment regimens [18, 19]. With the disease progression and the prolonged disease duration, there is a progressive deterioration in β-cell mass and function in T2DM patients. Longer diabetes duration will contribute to the poor glycemic control. A retrospective study of the Diabcare-China surveys showed that patients treated with oral antidiabetics alone decreased from 75 % in 1998 to 50 % in 2006, while patients on insulin or in combination with oral antidiabetics were greater in 2006 [20]. In contrast, the glycemic control rate improved significantly from 1998 to 2006, and significantly more patients reached HbA1c < 7 % or ≤ 6.5 % in 2006 [20]. Therefore, we should strengthen the follow-up, management, and intervention for T2DM patients with longer duration or complex treatment regimens.

There were some limitations in this study. The missing data in the present study may compromise the results, and no data about hypoglycemic events were included. We did not consider lack of self-care management knowledge [21] and poor compliance [22] due to the nature of observational study. The recruited patients in this study cannot represent all diabetic patients in other cities of China.

In conclusion, the situation of glycemic control was not satisfactory in Nanjing communities. Various factors are associated with the poor glycemic control. Management and intervention according to the associated factors should be implicated to strengthen the diabetes management and improve the glycemic control in this population.

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Compliance with ethical standards

Conflict of interest None.

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