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ORIGINAL RESEARCH

Risk Factors for Glycemic Control in Hospitalized Patients with Type 2 Diabetes Receiving Continuous Subcutaneous Insulin Infusion Therapy

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ABSTRACT

Introduction: Patients with diabetes are confronted with numerous obstacles to achieve adequate glycemic control during hospitalization. The aim of this study was to explore the risk factors associated with glycemic control in hospitalized patients with type 2 diabetes mellitus (T2DM) treated with continuous subcutaneous insulin infusion (CSII).

Methods: This cross-sectional study included 5223 patients hospitalized with T2DM in a tertiary hospital in Xiamen (China) between January 2017 and December 2019. All patients were managed according to established protocols for glycemic monitoring and insulin pump treatment regimens. Demographic information and clinical profiles were collected from electronic health records. Multiple linear regression analysis was used to identify the risk factors associated with glycemic control.

Results: Among the 5223 hospitalized patients with T2DM receiving CSII therapy, 55.2% achieved their ideal blood glucose level (3.9–10.0 mmol/L), 44.5% experienced hyperglycemia (> 10.0 mmol/L), and 0.3% experienced hypoglycemia (< 3.9 mmol/L) during their hospitalization. Multivariate analyses showed that among inpatients with T2DM, older age, male gender, higher low-density lipoprotein-cholesterol (LDL-C) level, lower C-peptide (C-P) level, lower body mass index (BMI), longer duration of diabetes, previous insulin prescriptions, nephropathy, and retinopathy were factors more likely to be associated with a blood glucose level in the hyperglycemic range ($P < 0.05$). We also observed that among hospitalized patients with T2DM, those with lower BMI, lower C-P, lower LDL-C, longer disease duration, and previous insulin prescriptions were more likely to correlate with a higher proportion of hypoglycemia range (all $P < 0.05$).

Conclusion: Older age, male gender, lower BMI, lower C-P, higher LDL-C, previous insulin

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prescriptions, longer duration of diabetes, nephropathy, and retinopathy may be risk factors for a higher proportion of hyperglycemic events in hospitalized patients with T2DM under CSII therapy. Furthermore, lower BMI, lower C-P, lower LDL-C, longer duration of diabetes, and previous insulin prescriptions were found to be important factors for a higher proportion of hypoglycemic events. Evaluating the clinical features, comorbidities, and complications of hospitalized patients is essential to achieve reasonable glycemic control.

Keywords: Type 2 diabetes mellitus; Hospitalized patients; Glycemic control; Continuous subcutaneous insulin infusion; Risk factors

Key Summary Points
Why carry out this study?
Patients with diabetes are confronted with numerous obstacles to achieve adequate glycemic control during hospitalization.
It is important to determine the risk factors associated with glycemic control in hospitalized patients with type 2 diabetes mellitus (T2DM) treated with continuous subcutaneous insulin infusion (CSII).
What has been learned from the study?
Older age, male gender, lower body mass index (BMI), lower C-peptide (C-P) level, higher low-density lipoprotein-cholesterol (LDL-C), previous insulin prescriptions, longer duration of diabetes, nephropathy, and retinopathy may be risk factors for a higher proportion of hyperglycemia in hospitalized patients with T2DM receiving CSII therapy.
Patients with lower BMI, lower C-P, lower LDL-C, longer duration of diabetes, and previous insulin prescriptions were prone to a higher proportion of hypoglycemic events.
Clinicians should assess these clinical characteristics, comorbidity, and complications in hospitalized patients for good glycemic control.

INTRODUCTION

Diabetes has increasingly become a major public health problem and an escalating economic burden in China. According to the nationally representative epidemiological survey published in 2020, the overall prevalence of diabetes in mainland China in 2017 was 11.2% using World Health Organization criteria. Unfortunately, only 49.2% of treated patients in this survey achieved glucose control goals [1]. Furthermore, according to the ARCH Project, the majority of patients with diabetes in China were admitted due to poor glucose control, followed by chronic complications [2]. Primary care coverage in China is inadequate to provide the care needed, with the result that a significant number of people with diabetes suffer from persistent hyperglycemia, which subsequently leads to hospitalization. In addition, in some parts of China, reimbursement is only possible if the individual is hospitalized, which explains the relatively high hospitalization rate of patients with diabetes. How to achieve better glucose control to reduce the duration of hospitalization and improve clinical outcomes has become an important issue to solve.

Extensive evidence demonstrates that both hyperglycemia and hypoglycemia in hospitalized patients with diabetes are associated with longer hospitalization and poor clinical outcomes, including increased re-admissions and mortality, infections, and in-hospital complications [3–8]. In the inpatient setting, insulin therapy has been shown to reduce mortality and morbidity in critically ill patients in the surgical intensive care unit and to decrease morbidity among patients in the medical intensive care unit [9, 10]. Clinical guidelines [11–13] have recommended that intensive insulin therapies, such as continuous subcutaneous insulin infusion (CSII) and multiple subcutaneous insulin injections (MDI), are the preferred treatments for hyperglycemia in hospitalized patients. Data retrieved for the literature suggest that the use of insulin pumps can improve glycemic control, reduce insulin dosage, and decrease rates of hypoglycemia compared to MDI [14, 15].

Patients with diabetes must confront numerous obstacles to achieve adequate glycemic control during hospitalization. Most published studies have investigated the association between glucose control during hospitalization and different factors, such as, for example, obesity, disease duration, hemoglobin A1c (HbA1c) on admission, and diabetes-related complications [16–19]. However, there is limited information on the clinical characteristics and complications among hospitalized patients receiving CSII therapy and the association of the above factors with glucose control. Therefore, this cross-sectional study was performed to identify risk factors for glycemic control (target control of glycemia, hyperglycemia, and hypoglycemia) in hospitalized patients with type 2 diabetes mellitus (T2DM) receiving CSII therapy.

METHODS

Study Population

A total of 5223 patients with T2DM who were treated at the Department of Endocrinology and Diabetes, First Affiliated Hospital of Xiamen University, Xiamen, China from January 2017 to December 2019 were included in this cross-sectional study. All patients were managed according to established protocols for glycemic monitoring and insulin pump treatment regimens.

Inclusion and Exclusion Criteria

To be eligible for inclusion, patients were $\geq$ 18 years of age and had been diagnosed with T2DM at the time of inclusion in the study. Patients were not eligible for the study if pregnant or contemplating pregnancy, had an infection, and/or experienced hypoglycemic episodes, ketoacidosis, hypertonic coma, and other acute complications 7 days before inclusion.

Inpatient Glucose Control

All patients were transitioned to Humalog rapid-acting insulin (insulin lispro; Eli Lilly, Indianapolis, IN, USA) using the MiniMed Paradigm 722 insulin pump (Medtronic, Northridge, CA, USA). The initial daily insulin dosage was calculated as follows: total insulin dose daily = 0.7 U $\times$ body weight (kg). The basal rate (units/hour) was calculated as 50% of the total insulin dose, and the other 50% was administered as a pre-prandial bolus before each meal. The dawn phenomenon and nocturnal hypoglycemia were taken into account, and the basal rate was fixed depending on the period: basal insulin dose/24 $\times$ 0.8 between 22:00 h and 03:00 h; basal insulin dose/24 $\times$ 1.2 between 03:00 h and 07:00 h; basal insulin dose/24 $\times$ 1.0 between 07:00 h and 22:00 h. The basal and bolus doses of insulin infusion were tailored every 2 days by one professional doctor according to the capillary blood glucose level to achieve the glycemic target (fasting blood glucose $<$ 7.0 mmol/L and average postprandial blood glucose $<$ 10.0 mmol/L). All patients underwent the same educational program on lifestyle management, and their meals were provided by the hospital nutrition canteen during the hospitalization period, with the meals containing a balanced dietary ratio of 50–55% carbohydrate, 15–20% protein and 20–30% fat. Capillary blood glucose was monitored at the time the patients started CSII and thereafter at least 7 times per day (before and 2 h after each meal and at bedtime) by trained nurses using a unified glucometer. The management of hypoglycemia during hospitalization was in line with previous published guidelines [20]. We defined the ideal blood glucose range for hospitalized patients as 3.9–-10.0 mmol/L [21], the hypoglycemia range for hospitalized patients as $<$ 3.9 mmol/L and the hyperglycemia range for hospitalized patients as $>$ 10.0 mmol/L, then calculated the percentage of capillary blood glucose measurements within the range among all blood glucose measurements as: percentage of capillary blood glucose measurements = number of blood glucose measurements within range/all blood glucose measurements $\times$ 100.

Data Collection

Data were collected from electronic health records in the hospital. For each admission, a medical interview and examinations were undertaken to confirm each patient was were free of infection and other acute conditions, such as ongoing treatment for malignancies and not currently using steroids. The clinical condition and medical history of all participants were obtained, including smoking history, alcohol consumption habits, past medical history, previous hospitalizations, and regular use of antidiabetic drugs, etc. Blood and urine samples were taken the day following admission.

Clinical Variables and Laboratory Data

Height and weight were measured by trained nurses according to the standard protocol. Body mass index (BMI) was calculated by weight (kilograms) divided by height squared (meters). HbA1c was measured with a high-performance liquid chromatography method, a standardized diagnosis based on International Federation of Clinical Chemistry (IFCC) criteria. The estimated glomerular filtration rate) was defined by the four-variable Modification of Diet in Renal Disease study equation [22].

Comorbidities and Complications

Hypertension was diagnosed as systolic blood pressure $\geq$ 140 mmHg and/or diastolic blood pressure $\geq$ 90 mmHg and/or the use of antihypertension drugs [23]. Hyperlipidemia was defined as a total cholesterol $>$ 6.2 mmol/L, triglycerides $>$ 2.2 mmol/L, or low-density lipoprotein-cholesterol (LDL-C) $>$ 3.3 mmol/L [24]. The major complications of T2DM considered in this study included myocardial infarction (MI), ischemic heart disease, heart failure, arteriosclerosis, arrhythmia, and diabetes-related complications such as nephropathy, retinopathy, and neuropathy, all of which were obtained from medical records and verified by consulting physicians.

Ethical Considerations

This study was approved by the Ethics Committee of The First Affiliated Hospital of Xiamen University (Number: 2020–055) and conducted in accordance with the rules of the Declaration of Helsinki of 1975, revised in 2013. All subjects agreed to participate in this study and signed the informed consent form.

Statistical Analysis

All analyses were conducted with SAS software, version 9.1 (SAS Institute, Cary, NC, USA). The level of significance for all tests was two-tailed and set at $P < 0.05$. Data were summarized as the mean $\pm$ standard deviation (SD), median with interquartile range or percentages where appropriate. The associations between blood glucose range and clinical and laboratory variables with comorbidity and complications of T2DM were assessed with the univariable and multivariable linear model and the outcomes shown as estimates, standard errors, and *P* values. Odds ratios (ORs) and 95% confidence intervals were calculated in SAS software, version 9.1 using the estimates.

RESULTS

Clinical and Laboratory Characteristics

Baseline characteristics are shown in Table 1. Among the 5223 patients, the mean age ($\pm$ SD) of participants was 53.5 $\pm$ 15.3 years, 55.5% were men, and the majority suffered from multimorbidities. The mean BMI of the patients was 24.2 $\pm$ 4.0 kg/m^2. The mean disease duration was 8.0 $\pm$ 3.2 years. Of the 5223 patients, 69.4% were insulin naïve. The laboratory data showed that the patients had a high HbA1c level (9.5 $\pm$ 2.5%. During hospitalization, the blood glucose level was measured no less than 7 times per day; the percentage of patients in the range of ideal blood glucose level, hyperglycemia, and hypoglycemia was 55.2%, 44.5%, and 0.3%, respectively.

Table 1 Baseline characteristics of patients hospitalized with type 2 diabetes mellitus

Variables	*N* = 5223 hospitalized patients
Demographic variables	
Gender	
Female, *n* (%)	2323 (44.5)
Male, *n* (%)	2900 (55.5)
Age (years)	53.5 ± 15.3
Clinical variables	
BMI (kg/m^2)	24.2 ± 4.0
Disease duration (years)	8.0 ± 3.2
Economic variables	
Hospital costs (¥)	9448.6 ± 7724.2
Laboratory variables	
SBP (mmHg)	132.8 ± 20.4
DBP (mmHg)	80.1 ± 10.7
C-P (ng/mL)	1.4 [0.8–2.1]
TC (mmol/L)	5.0 ± 1.4
LDL-C (mmol/L)	2.7 ± 1.0
Insulin use before admission, *n* (%)	3624 (69.4)
HbA1c (%)	9.5 ± 2.5
eGFR (mL/min/1.73m^2)	91.9 ± 34.7
Mean % of BG measurements within the ideal glucose range (3.9 – 10.0 mmol/L)	55.2
Mean % of BG measurements within the hyperglycemic range (> 10.0 mmol/L)	44.5
Mean % of BG measurements within the hypoglycemic range (< 3.9 mmol/L)	0.3
Comorbidity	
Hypertension, *n* (%)	2079 (39.8)
Hyperlipidemia, *n* (%)	2159 (41.3)
Cancer, *n* (%)	225 (4.3)
Complications	
Myocardial infarction, *n* (%)	23 (0.4)
Ischemic heart disease, *n* (%)	81 (1.6)
Heart failure, *n* (%)	276 (5.3)
Arteriosclerosis, *n* (%)	1624 (31.1)
Arrhythmia, *n* (%)	332 (6.4)
Nephropathy, *n* (%)	1046 (20.0)
Retinopathy, *n* (%)	1929 (36.9)
Neuropathy, *n* (%)	1405 (26.9)
Peripheral vascular disease, *n* (%)	947 (18.1)

Data are presented as the mean ± standard deviation (SD) or as the median with the interquartile range (25th percentile, 75th percentile) given in square brackets, unless indicated otherwise

BMI body mass index, *SBP* systolic blood pressure, *C-P* C-peptide, *TC* total cholesterol, *LDL-C* low-density lipoprotein-cholesterol, *HbA1c* hemoglobin A1c, *eGFR* estimated glomerular filtration rate

Comorbidities and Chronic Complications of Hospitalized Patients with T2DM Receiving CSII Therapy

A summary of the various comorbidities and complications of T2DM present in the patients is given in Table 1. Clinically diagnosed MI was reported in only 0.4% of the inpatients, and 36.9%, 26.9%, 20.0%, 31.1%, and 18.1%% of all inpatients had a history of retinopathy, neuropathy, nephropathy, arteriosclerosis or peripheral vascular disease, respectively. Patients who had a history of hypertension, hyperlipidemia, or cancer accounted for 39.8%, 41.3%, and 4.3%, respectively, of the total inpatient study population.

Table 2 Analysis of potential risk factors affecting the percentage of blood glucose measurements within the ideal glucose range by liner regression model

Variables	Univariate analysis			Multivariate analysis		
	Estimate β	95% CI	*P*	Estimate β	95% CI	*P*
Age	− 0.260	− 0.301 to − 0.218	< 0.001	− 0.245	− 0.301 to − 0.188	< 0.001
Male	− 2.368	− 3.667 to − 1.069	< 0.001	− 1.845	− 3.290 to − 0.399	0.012
BMI	0.817	0.656 to 0.978	< 0.001	0.493	0.304 to 0.681	< 0.001
SBP	− 0.078	− 0.110 to − 0.045	< 0.001	− 0.011	− 0.050 to 0.029	0.599
LDL–C	− 1.391	− 2.128 to − 0.646	< 0.001	− 2.196	− 2.950 to − 1.442	< 0.001
C–P	2.001	1.469 to 2.533	< 0.001	1.802	1.192 to 2.411	< 0.001
Insulin use before admission	− 7.864	− 9.234 to − 6.495	< 0.001	− 0.623	− 8.205 to − 5.041	< 0.001
Disease duration	− 0.771	− 0.967 to − 0.574	< 0.001	− 0.439	− 0.653 to − 0.226	< 0.001
Cancer	0.036	− 3.086 to 3.1574	0.982	2.827	− 0.603 to 6.256	0.106
Myocardial infarction	− 6.206	− 15.470 to 3.059	0.189	− 1.271	− 10.372 to 7.829	0.784
Ischemic heart disease	− 4.929	− 10.428 to 0.571	0.079	0.194	− 5.593 to 5.981	0.948
Heart failure	− 7.369	− 10.352 to − 4.386	< 0.001	− 3.343	− 6.788 to 0.103	0.057
Arteriosclerosis	− 4.896	− 6.300 to − 3.492	< 0.001	− 0.844	− 3.167 to 1.480	0.477
Arrhythmia	− 3.661	− 6.262 to − 1.060	0.006	− 1.274	− 4.201 to 1.653	0.394
Nephropathy	− 7.972	− 9.536 to − 6.408	< 0.001	− 4.521	− 6.445 to − 2.596	< 0.001
Retinopathy	− 6.486	− 7.798 to − 5.174	< 0.001	− 2.541	− 4.136 to − 0.946	0.002
Neuropathy	− 5.214	− 6.654 to − 3.773	< 0.001	0.520	− 1.194 to 2.234	0.552
Peripheral vascular disease	− 3.956	− 5.681 to − 2.231	< 0.001	0.849	− 1.779 to 3.477	0.527

The percentage of blood glucose measurements within the ideal glucose range (3.9–10.0 mmol/L)
CI Cconfidence interval

Risk Factors for the Percentage of Glycemic Measurements Within the Ideal Blood Glucose Range

Potential risk factors for the percentage of blood glucose measurements within the ideal glucose range by liner regression model are shown in Table 2. The results showed that male gender was a risk factor for not achieving the ideal glucose range. They also showed that younger age, higher BMI, lower systolic blood pressure (SBP), lower LDL-C, higher C-peptide (C-P), shorter disease duration, no previous insulin prescriptions, and no complications (heart failure, arteriosclerosis, arrhythmia, nephropathy, retinopathy, neuropathy, peripheral vascular disease) were factors that increased the likelihood of the patient falling within the target glycemic range (all $P < 0.01$). Using univariate and multivariate analysis, male gender was still associated with a greater difficulty in achieving a blood glucose level within the normal range. Additionally, hospitalized patients who were younger, had higher BMI, lower LDL-C, higher

Table 3 Association between variables and the percentage of blood glucose measurements within the hyperglycemic range in the study subjects

Variables	Univariate			Multivariate		
	Estimate β	95 %CI	*P*	Estimate β	95% CI	*P*
Age	0.262	0.221 to 0.304	< 0.001	0.247	0.191 to 0.304	< 0.001
Male	2.357	1.057 to 3.656	< 0.001	1.906	0.455 to 3.357	0.010
BMI	− 0.781	− 0.942 to − 0.620	< 0.001	− 0.466	− 0.656 to − 0.277	< 0.001
SBP	0.080	0.048 to 0.112	< 0.001	0.012	− 0.028 to 0.052	0.556
LDL–C	1.455	0.719 to 2.192	< 0.001	2.236	1.480 to 2.993	< 0.001
C–P	− 1.955	− 2.488 to − 1.423	< 0.001	− 1.769	− 2.381 to − 1.157	< 0.001
Insulin use before admission	7.707	6.336 to 9.078	< 0.001	6.511	4.924 to 8.099	< 0.001
Disease duration	0.712	0.516 to 0.909	< 0.001	0.423	0.209 to 0.637	< 0.001
Cancer	− 0.446	− 3.568 to 2.677	0.780	− 2.882	− 6.324 to 0.559	0.101
Myocardial infarction	6.373	− 2.895 to 15.641	0.178	1.495	− 7.638 to 10.627	0.748
Ischemic heart disease	4.859	− 0.643 to 10.360	0.083	− 0.384	− 6.192 to 5.423	0.897
Heart failure	7.324	4.340 to 10.308	< 0.001	3.210	− 0.248 to 6.668	0.069
Arteriosclerosis	4.907	3.502 to 6.311	< 0.001	0.875	− 1.457 to 3.207	0.462
Arrhythmia	3.661	1.059 to 6.263	0.006	1.207	− 1.731 to 4.144	0.421
Nephropathy	7.999	6.434 to 9.563	< 0.001	4.485	2.553 to 6.416	< 0.001
Retinopathy	6.552	5.240 to 7.864	< 0.001	2.590	0.989 to 4.191	0.002
Neuropathy	5.139	3.698 to 6.581	< 0.001	− 0.477	− 2.197 to 1.243	0.587
Peripheral vascular disease	3.928	2.203 to 5.654	< 0.001	− 0.847	− 3.484 to 1.791	0.529

The percentage of blood glucose measurements within the hyperglycemic range (> 10.0 mmol/L)

C-P, insulin naïve, shorter disease duration, and were without complications in terms of nephropathy and retinopathy were more likely to achieve the target glycemic range (all $P < 0.05$).

Risk Factor for the Percentage of Glycemic Measurements Within the Hyperglycemic Range

Table 3 shows the blood glucose measurements in the hyperglycemic range and related factors in hospitalized patients with T2DM. The univariate analysis showed that patients who were older, male sex, had lower BMI, lower C-P, higher SBP, higher LDL-C, longer duration of diabetes, previous use of insulin, complications for heart failure, arteriosclerosis, arrhythmia neuropathy, retinopathy, and peripheral vascular disease were more likely to be hyperglycemic (all $P < 0.05$). By both univariate analysis and multivariate analysis, the results were completely opposite to blood glucose in the target range. Patients with older age, male gender, lower BMI, higher LDL-C, lower C-P, previous use of insulin, longer duration of diabetes, nephropathy, and retinopathy were more likely to be hyperglycemic (all $P < 0.05$).

Table 4 Predictors of the percentage of blood glucose measurements within the hypoglycemic range on the basis of linear regression models

Variables	Univariate			Multivariate		
	Estimate β	95% CI	*P*	Estimate β	95% CI	*P*
Age	− 0.003	− 0.006 to − 0.000	0.027	− 0.002	− 0.005 to 0.000	0.089
Male	0.000	− 0.079 to 0.080	0.995	− 0.065	− 0.128 to − 0.003	0.041
BMI	− 0.034	− 0.041 to − 0.028	< 0.001	− 0.025	− 0.033 to − 0.017	< 0.001
SBP	− 0.002	− 0.004 to − 0.000	0.027	− 0.001	− 0.003 to 0.001	0.236
LDL− C	− 0.055	− 0.103 to − 0.008	0.023	− 0.034	− 0.066 to − 0.001	0.043
C− P	− 0.047	− 0.081 to − 0.013	0.007	− 0.026	− 0.052 to − 0.000	0.049
Insulin use before admission	0.165	0.080 to 0.250	< 0.001	0.134	0.066 to 0.201	< 0.001
Disease duration	0.056	0.044 to 0.068	< 0.001	0.014	0.005 to 0.023	0.002
Cancer	0.376	0.185 to 0.567	< 0.001	0.004	− 0.143 to 0.152	0.953
Myocardial infarction	− 0.153	− 0.721 to 0.414	0.597	− 0.176	− 0.568 to 0.216	0.379
Ischemic heart disease	− 0.150	− 0.487 to 0.187	0.384	− 0.042	− 0.292 to 0.208	0.744
Heart failure	− 0.017	− 0.200 to 0.167	0.859	0.106	− 0.043 to 0.255	0.163
Arteriosclerosis	− 0.041	− 0.127 to 0.046	0.354	− 0.071	− 0.172 to 0.029	0.162
Arrhythmia	− 0.056	− 0.216 to 0.103	0.489	0.023	− 0.103 to 0.149	0.721
Microvascular complications	− 0.015	− 0.094 to 0.065	0.717	− 0.059	− 0.125 to 0.007	0.082
Peripheral vascular disease	0.012	− 0.094 to 0.118	0.820	0.016	− 0.097 to 0.129	0.784

The percentage of blood glucose measurements within the hypoglycemic range (< 3.9 mmol/L)

Risk Factor for the Percentage of Glycemic Measurements Within the Hypoglycemic Range

Predictors of the percentage of blood glucose measurements within the hypoglycemic range on the basis of linear regression models are shown in Table 4. The univariate analysis showed that patients who were younger, had lower BMI, lower SBP, lower LDL-C, lower C-P, previous use of insulin, longer disease duration, and had a history of cancer easily presented blood glucose in the hypoglycemic range ($P < 0.05$). By both univariate and multivariate analysis, patients had lower BMI, lower LDL-C, lower C-P, previous use of insulin, and longer disease duration were more likely to have measured hypoglycemia. Patients with male gender were less likely to be within the hypoglycemia range (all $P < 0.05$).

DISCUSSION

In this study, we observed that among hospitalized patients with T2DM treated with CSII, those individuals with older age, male gender, lower BMI, lower C-P, higher LDL-C, previous insulin prescriptions, longer duration of diabetes, and complications of nephropathy or retinopathy were less likely to be controlled within the ideal glucose range and more likely to maintain a high-proportion of hyperglycemia. In addition, our findings showed that individuals who had lower BMI, lower LDL-C, lower C-P, longer duration of diabetes, and

previous use of insulin were prone to a higher percentage of hypoglycemia, and that the male gender was associated with a decreased risk of a high percentage of hypoglycemia.

The American Diabetes Association's (ADA) guidelines list of factors involved in increasing the risk of treatment-associated hypoglycemia include the use of insulin or insulin secretagogues, impaired kidney or hepatic function, longer duration of diabetes, frailty, older age, cognitive impairment, impaired counterregulatory response, alcohol use, polypharmacy (especially angiotensin-converting-enzyme [ACE] inhibitors, angiotensin receptor blockers, nonselective β-blockers) [25], among others. The results of the present study demonstrated that patients with lower BMI, longer duration of diabetes, lower C-P levels, and former use of insulin were prone to hypoglycemia during CSII treatment. Given the known feature of progressive β-cell dysfunction in T2DM [26], those with low C-P levels, previous insulin prescriptions, and longer duration of diabetes typically have more profound β-cell dysfunction and therefore are not easily controlled within the euglycemic range even on CSII therapy.

Of the participants in this study, 55.52% were male. After the statistical analysis, we noted that male gender was associated with a greater difficulty to achieve control of blood glucose in the normal range (OR – 1.845) and with a lower risk of high percentages of hypoglycemia (OR – 0.065). Quilliam et al. [27] also noted a negative association between hypoglycemia and the male gender (OR 0.84). This could be due to the different characteristics of the enrolled population. Additionally, our present study demonstrated that the blood glucose level of inpatients receiving CSII therapy who were older, had higher LDL-C levels, nephropathy, and retinopathy was difficult to control within the normal range under CSII therapy. This is consistent with previous evidence [17, 28, 29] that inadequate glycemic control is common in older patients with T2DM and that those with longer duration of disease are more likely to have a variety of comorbidities and diabetes-related complications.

Our data also demonstrated a high frequency of chronic complications associated with T2DM inpatients in Xiamen, China. A cross-sectional survey of inpatients with T2DM in China during 1991–2000 conducted by the Chinese Diabetes Society showed that the prevalence rates of chronic diabetic complications and related macrovascular diseases were 31.9% for hypertension, 12.2% for cerebrovascular diseases, 15.9% for cardiovascular diseases, 5.0% for lower extremity vascular diseases, 34.3% for eye diseases, 33.6% for nephropathy, and 60.3% for neuropathy, with an overall prevalence of 73.2% for chronic diabetic complications and macrovascular disease [12]. In our study, we noted a lower incidence of nephropathy and neuropathy, and a slightly higher prevalence of hypertension and retinopathy compared with the 1991–2000 survey [12]. One study presented results showing that hypertension was the most common condition of all the comorbidity burden of T2DM, with a higher prevalence approaching up to 44.3% [30]. Our study showed a comparable prevalence of 39.8%, with a negative estimate of β (– 0.078) for the univariate analysis between SBP and adequate glycemic control. It is noteworthy that comorbidities and complications may not be the risk factors for glycemic control, but also the results of former inadequate glycemic control [24]. Controlling blood glucose levels, as well as managing diabetes-related comorbidities and complications, remains a big challenge.

Although this study has the advantages of large sample size and high consistency of treatment regimens, it also has some limitations. First, all hospitalized patients were enrolled from one center in China, which may limit the universality of our outcomes to the general population. Second, this cross-sectional design could not establish a temporal association between clinical characteristics and blood glucose control. Third, the blood glucose levels in this study were not continuously monitored, and were monitored for < 14 days, which is different from the concept of target in the range, target above the range, and target below the range described in continuous glucose monitoring [21]. Nevertheless, this slight difference has minimal effect on the evaluation of the overall results.

CONCLUSION

Our data revealed that clinical characteristics, comorbidities, and complications may play a significant role in glycemic control for hospitalized patients with T2DM on CSII therapy. Age, male gender, lower BMI, lower C-P, higher LDL-C levels, longer duration of diabetes, previous use of insulin, and complications of nephropathy or retinopathy were factors increasing the likelihood that patients would present a high percentage of hyperglycemia. Furthermore, patients with lower BMI, lower C-P, lower LDL-C levels, longer duration of diabetes, and previous insulin prescriptions were prone to a high proportion of hypoglycemia. These findings suggest that clinicians should assess these clinical characteristics, comorbidity, and complications in hospitalized patients with the aim to achieve good glycemic control. These results need to be confirmed in future studies with a multiracial population.

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Data Availability. The data used to support the findings of this study are available from the corresponding author upon request.

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