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Cost-Effectiveness Analysis of Insulin Pump Therapy for Patients with Type 2 Diabetes Mellitus in the Perioperative Period

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Abstract: Objective: In recent years, insulin pump, as one of the effective glycemic control therapy in perioperative hyperglycemia patients, has been gradually applied and promoted in clinical type 2 diabetes patients, but there is a contradictory statements of whther it is ecomonical. To analyze the cost and effect of perioperative insulin pump treatment in patients with type 2 diabetes, this artical compared the cost-effectiveness of glucose control in the perioperative insulin pump treatment group (CSII group) with multiple daily subcutaneous insulin treatment group (MDI group) and subcutaneous insulin + oral hypoglycemic drug treatment group (subcutaneous + oral treatment group). Methods: This study is based on the cost-effectiveness analysis method, compared the difference in glucose-control treatment costs and treatment effect of the three perioperative glucose control schemes, and conducted the sensitivity analysis of the corresponding indicators. Results: The comparison of the basic data between the three patient groups was not significantly significant ($P > 0.05$), and it was comparable. The fastest in CSII was (3.52 ± 2.94) days, and the incidence of postoperative infection in CSII patients was basically the same as that in the subcutaneous + oral treatment group, with 12.9% and 12.5%, respectively. The savings in CSII, MDI and subcutaneous + oral treatment by 1d were 609.07, 343.83 and 311.25, respectively, much more in CSII than MDI and subcutaneous + oral treatment; reducing the postoperative infection rate by 1 percentage point was 166.20, 60.34 and 135.70, respectively, in CSII than MDI and subcutaneous + oral treatment. Comprehensive analysis shows that CSII has a good cost-effectiveness. The results of sensitivity analysis showed the credibility and stability of this study. Conclusions: Insulin pump treatment in perioperative type 2 diabetes patients is a cost-effectiveness treatment scheme, and it is very useful in perioperative type 2 diabetes patients.

Keywords: Perioperative, Type 2 Diabetes, Insulin Pump, Cost-Effectiveness Analysis

1. Introduction

The high incidence of Diabetes Mellitus (DM) [1], and the various complications of diabetes in China [2], puts a greater burden on the country, society and patients' families. Studies have shown [3] that from 25% to 50% of people with diabetes experience one surgery in their lifetime. Surgery is a major factor in blood glucose fluctuations in diabetics [4], Perioperative hyperglycemia [5] can bring a variety of hazards to the human body [6]. Several studies have shown that perioperative hyperglycemia increases poor wound healing and infection in patients [7], even the risk of death [8]. In recent years, insulin pump treatment, as one of the effective glycemic control programs in perioperative hyperglycemia patients, has been gradually applied and promoted in clinical type 2 diabetes patients, but there is a problem of large cost [9], which affected the compliance with patients. Therefore, it is very important to analyze the cost-effectiveness of insulin pump use in patients with type 2 diabetes. Cost-effectiveness Analysis (CEA) is a comprehensive economic analysis method, this study by comparing CSII group and MDI group and subcutaneous + oral treatment group and cost-effectiveness of glucose control cost, treatment effect, analyze the application of insulin pump treatment, in order to promote clinical application of insulin pump treatment to provide reference.

2. Data and Methods

2.1. Source of Information

Perioperative type 2 diabetes patients who underwent elective surgery from March 2, 2020 to May, 2021 were selected as the study subjects.

2.2. Case Inclusion, Exclusion, and Exclusion Criteria

2.2.1. Inclusion Criteria

(1) Patients with type 2 diabetes who meet the 1999 WHO diabetes diagnostic criteria; (2) Patients underwent elective surgery; (3) Patients with insulin pump / multiple daily subcutaneous insulin / subcutaneous insulin + oral glucose control; (4) Patients with preoperative fasting glucose> 7.8 mmol/L and random glucose> 10mmol / L;

2.2.2. Exclusion Criteria

(1) Patients' hospitalization days of less than 3d; (2) gestational diabetes patients; (3) Alcohol abuse and mental disorders; (4) Patients with two or more operations during one hospitalization; (5) Patients with diabetic ketoacidosis and severe infection and hormone use; (6) Patients with serious heart, liver, kidney diseases or other serious endocrine diseases;

2.3. Statistical Analysis Methods

Excel 2019 was used to establish a database, collect relevant data and cost-effectiveness indicators of the research subjects, and apply SPSS26.0 software to analyze the data by statistics. The basic information of patients was descriptive analysis, continuity data by mean ± standard deviation or median (95% confidence interval), count data by frequency and percentage (%), and non-parametric test. In the effect index, the difference analysis of low composition ratio or rate, using chi-square test (statistic is χ^2); For data conforming to normal distribution, independent sample T test (statistics t), one-way ANOVA (statistics F), Mann-Whitney U test (statistics z) for biased data, and Kruskal-Wallis H test between three groups (statistics χ^2), With =0.05 and P <0. 05 was considered as statistically significant.

3. Results

3.1. General Description of the Data

In this study, 176 patients with perioperative type 2 diabetes in a tertiary hospital from March 2020 to May 2021 were selected, including 93 patients in CSII group, 43 patients in MDI group and 40 patients in subcutaneous + oral treatment group. All of the enrolled patients were eligible for the diagnosis of perioperative hyperglycemia. Of the 176 subjects, mean age (63.36± 12.59), 90 men, mean age (63.46 ± 12.56), and 86 women, mean age (63.26 ± 12.70), including CSII (62.76 ±12.87), MDI (62.16± 12.79), and subcutaneous + oral treatment (66.03 ± 11.63). Of the three patient groups, 23.3% were patients involved in orthopedic surgery, 24.4% had urological surgery patients, and 18.7% had gastrointestinal surgery. Fasting blood glucose levels and (or) postprandial blood glucose levels of the patients in the CSII and MDI groups were consistent with those treated with an insulin pump. Blood glucose of all three groups reached the standard after treatment. Comparing the sociodemographic data of sex, age, occupation, the type of surgery and anesthesia among the three groups, the results showed that the basic conditions of the CSII, MDI, and subcutaneous + oral treatment groups were not significantly different (*P*> 0.05) and were comparable.

Table 1. *Basic information of the three groups.*

project		CSII group	MDI group	Subcutaneous + oral treatment group	statistics	*P*
sex	man	40 (43.0)	27 (62.8)	23 (57.5)	5.44[a]	0.07
	woman	53 (57.0)	16 (37.2)	17 (42.5)		
age	≤ 44 years old	79 (7.5)	3 (7.0)	1 (2.5)	1.61[d]	0.45
	45-59 Years old	28 (30.1)	13 (30.2)	10 (25.0)		
	≥60 years old	58 (62.4)	27 (62.8)	29 (72.5)		
religion	No religious belief	91 (97.8)	43 (100)	40 (100)	1.81[a]	0.41
	Have a religious belief	2 (2.2)	0	0		
nation	the Han nationality	92 (98.9)	43 (100)	40 (100)	0.90[a]	0.64
	minority nationality	1 (1.1)	0	0		
Occupation	retired	24 (25.8)	6 (14.0)	3 (7.5)		
	be on the job	9 (9.7)	6 (14.0)	5 (12.5)	11.53[a]	0.17
	unemployed	50 (53.8)	23 (53.5)	27 (67.5)		
	other	8 (8.6)	8 (18.6)	5 (12.5)		

project		CSII group	MDI group	Subcutaneous + oral treatment group	statistics	*P*
Education	Primary school and below	41 (44.1)	15934.9)	19 (47.5)	13.62[a]	0.13
	junior middle school	23 (24.7)	8 (18.6)	1 (2.5)		
	High school and technical secondary school	18 (19.4)	16 (37.2)	14 (35.0)		
	College degree or above	11 (11.8)	4 (9.3)	6 (15.0)		
Pay way	at public expense	7 (7.5)	2 (4.7)	1 (2.5)	9.68[a]	0.47
	Urban health care	52 (55.9)	22 (51.2)	17 (42.5)		
	Employee medical insurance	11 (11.8)	7 (16.3)	8 (20.0)		
	New rural cooperative	15 (16.1)	4 (9.3)	7 (17.5)		
	at one's own expense	7 (7.5)	8 (18.6)	7 (17.5)		
Anaesthesia way	general anesthesia	55 (59.1)	20 (46.5)	23 (57.5)	2.15[a]	0.71
	intravertebral anesthesia	28 (31.1)	18 (41.9)	1 (32.5)		
	local anesthesia	10 (10.8)	5 (11.6)	4 (10.0)		
surgical operation time	The procedure lasted for> 60min	75 (80.6)	28 (65.1)	3 (77.5)	3.96[a]	0.14
	The procedure lasted for 60min	18 (19.4)	15 (34.9)	9 (22.5)		
Whether to fast before surgery	yes	79 (84.9)	38 (88.4)	36 (90.0)	0.73[a]	0.70
	no	14 (15.1)	5 (11.6)	4 (10.0)		
Whether to fast after surgery	yes	83 (89.2)	38 (88.4)	36 (90.0)	0.06[a]	0.97
	no	10 (10.8)	5 (11.6)	4 (10.0)		
test result	LDL*	2.53±0.85	2.13±0.79	2.16±0.88	4.44[b]	0.01
	HDL*	0.95±0.28	0.96±0.32	0.94±0.26	0.06[b]	0.95
	cholesterol total*	4.25±1.35	4.12±1.29	4.07±1.22	0.32[b]	0.72
	glycerin trilaurate*	1.87 (1.32, 2.39)	1.61 (1.10, 1.61)	1.67 (1.10, 2.30)	4.86[c]	0.09
	fasting blood-glucose*	10.10 (10.36~13.20)	8.40 (8.24~9.03)	7.90 (7.68~8.16)	55.16[c]	0.00
	Blood glucose at 2 hours after breakfast*	14.10 (13.90~15.65)	11.20 (11.02~12.87)	10.25 (9.38~10.45)	52.05[c]	0.00
	Blood glucose at 2 hours after lunch*	14.10 (13.98~16.05)	13.20 (12.23~14.59)	11.20 (10.34~11.61)	23.59[c]	0.00
	Blood glucose for 2 hours after dinner*	13.60 (13.18~14.88)	11.90 (11.48~13.80)	10.60 (10.19~11.76)	18.18[c]	0.00
	Blood glucose before bed*	11.60 (11.86~13.49)	9.90 (9.87~11.76)	10.00 (9.77~11.17)	13.27[c]	0.00

Note: occupation-Other includes: self-employed, teachers, drivers, doctors, etc.; * The unit is mmol/L; [a]The Chi-square test was used (the statistic is χ^2); [b]One-way ANOVA (statistic: F) was used; [c]Analysis was performed using the Kruskal-Wallis H test (statistic is χ^2); [d]The rank-sum test was used.

3.2. Cost-Effectiveness Analysis

3.2.1. Costing Calculation

Cost-effectiveness analysis needs to strictly determine the cost index according to the research perspective, because the scope and size of the cost value directly affect the accuracy of the evaluation [11]. The cost of glucose control is beneficial to directly reflect the size of the cost required by the glucose control regimen. In this study, the cost of glucose control treatment of the three groups was used for the cost-effectiveness ratio calculation of each group. The cost of glucose control treatment of the CSII group / MDI group / subcutaneous group + oral treatment group = drug cost + treatment material cost + doctor treatment fee + test fee + treatment cost. The cost of glucose-controlled treatment for patients in the CSII, MDI and subcutaneous + oral treatment groups were 2143.93 ± 878.26 yuan, 1822.28 ± 1017.30 yuan and 1696.30 ±916.42 yuan, respectively, as detailed in Table 2.

Table 2. *Analysis of glucose control-related costs in the three groups.*

class*	CSII group	MDI group	Subcutaneous + oral treatment group	statistics	*P*
expenses for medicine	96.62 (83.78~109.46)	186.15 (140.37~231.93)	210.04 (148.83~271.25)	20.76a	0.00
Treatment material fee	454.61 (409.74~499.48)	1187.30 (982.02~1392.59)	1099.69 (907.40~1291.98)	80.52a	0.00
Doctor diagnosis and treatment fee	42.15 (40.61~43.69)	17.67 (15.68~9.67)	20.00 (18.55~21.45)	159.74a	0.00
surveyor's fee	632.28 (573.62~690.95)	342.84 (283.29~402.39)	341.51 (284.65~398.37)	52.58a	0.00
medical expense	918 (832.15~1004.37)	88.32 (71.27~105.37)	25.05 (18.42~31.69)	140.43a	0.00
Cost of glucose control treatment	2143.93±878.26	1822.28±1017.30	1696.30±916.42	3.96b	0.02

pour:*Unit for yuan; [a]Analysis was performed using the Kruskal-Wallis H test (the statistic is χ^2); [b]One-way ANOVA (the statistic is F) was used.

3.2.2. Evaluation of Glucose Control Effect

The results of the three groups showed that the difference between the glucose compliance time and the incidence of postoperative infection (*P* <0.05) was (3.52 ± 2.94) days in the CSII group, and the incidence of postoperative infection in the CSII group was 12.9% and 12.5%, respectively, as shown in Table 3.

Table 3. *Analysis of the effect index of glucose control of patients in the three groups.*

project	CSII group	MDI group	Subcutaneous + oral treatment group	statistics	P
Blood glucose compliance time (days)	3.52±2.94	5.30±3.53	5.45±4.85	5.87[a]	0.00
Standard average daily blood glucose (mmol/L)	8.49±1.52	8.50±1.47	8.46±1.20	0.01[a]	0.99
The incidence of hypoglycemia was (%)	29.00	30.20	12.50	4.67[b]	0.10
Postoperative incidence of infection was (%)	12.90	30.20	12.50	7.00[b]	0.03

pour: [a]One-way ANOVA (the statistic is F) was used; [b]The Chi-square test was used (the statistic is χ^2).

3.2.3. Cost-Effectiveness Analysis of the Three Glucose Control Schemes

cost-effectiveness ratio refers to the unit effect cost of calculation, through the cost of glucose treatment to shorten a blood glucose standard time saving cost, reduce the incidence of a postoperative infection by percentage of cost savings, etc., the higher the cost-effectiveness ratio shows that the treatment cost savings, the more economic and treatment effectiveness. The results showed that the cost saved by CSII, MDI and subcutaneous + oral treatment by 1d were 609.07, 343.83 and 311.25, respectively, in CSII, CSII than MDI and subcutaneous + oral treatment; reducing the postoperative infection rate by 1 percentage point was 166.20, 60.34 and 135.70, respectively, in CSII than MDI and subcutaneous + oral treatment. Comprehensive analysis concluded that CSII has good cost-effectiveness, as detailed in Table 4.

Table 4. *Cost-effectiveness Analysis of the three glucose control schemes.*

project	CSII group	MDI group	Subcutaneous + oral treatment group
Cost (Yuan)	2143.93	1822.28	1696.30
effect			
Blood glucose compliance time (d)	3.52	5.30	5.45
Postoperative incidence of infection was (%)	12.90	30.20	12.50
cost-effectiveness ratio			
Blood glucose standard time (Yuan / d)	609.07	343.83	311.25
Incidence of postoperative infection (Yuan /%)	166.20	60.34	135.70

3.2.4. Sensitivity Analysis of the Three Glucose-Control Regimens

(1) Cost sensitivity analysis of the three glucose control regimens.

With the implementation of economic level and medical reform policy, the cost of glucose control treatment tends to decrease. Combined with Table 4, comparing the cost results of the three glucose control schemes in Table 5, the sensitivity results of the two effect indexes of the three groups and the reduction of the unit postoperative infection rate, indicating that the CSII treatment scheme has better effect and economy. The cost-effectiveness analysis result of this study is stable and reliable.

Table 5. *Cost sensitivity analysis of the three glucose control schemes.*

project	Cost of this is-10%			Cost-20%			Cost + 10%		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Cost (Yuan)	1929.54	1640.05	1526.67	1715.15	1457.82	1357.04	2358.32	2004.51	1865.93
effect									
Blood glucose compliance time (d)	3.52	5.30	5.45	3.52	5.30	5.45	3.52	5.30	5.45
Postoperative incidence of infection was (%)	12.90	30.20	12.50	12.90	30.20	12.50	12.90	30.20	12.50
cost-effectiveness ratio									
Blood glucose standard time (Yuan / d)	548.16	309.44	280.12	487.26	275.06	249.00	669.98	378.21	342.37
Incidence of postoperative infection (Yuan /%)	149.58	54.31	122.13	132.96	48.27	108.56	182.82	66.37	149.27

Note: (1) is CSII group; (2) is MDI group, and (3) is subcutaneous + oral treatment group.

(2) Effect sensitivity analysis of the three glucose control regimens.

With the development of medical level, the incidence of hypoglycemia and postoperative infection tend to decrease. Combined with Table 4, comparing the cost size trend of the CSII group in Table 6 and the patients in the MDI and subcutaneous + oral treatment groups, respectively, the results showed that the sensitivity result of the two effect indicators in the three groups was consistent with the changed parameters before, indicating that the CSII treatment regimen has better effect and economy. The cost-effectiveness analysis results of this study are stable and reliable.

Table 6. *Effect sensitivity analysis of the three glucose control regimens.*

project	Incidence of hypoglycemia /% -10%			Incidence of postoperative infection /% -10%		
	(1)	(2)	(3)	(1)	(2)	(3)
Cost (Yuan)	2143.93	1822.28	1696.30	2143.93	1822.28	1696.30
effect						
The incidence of hypoglycemia was (%)	26.10	27.18	11.25			
Postoperative incidence of infection was (%)				11.60	27.18	11.25
cost-effectiveness ratio						
Incidence of hypoglycemia (Yuan /%)	82.14	67.04	150.78			
Incidence of postoperative infection (Yuan /%)				184.82	67.04	150.78

Note: (1) is CSII group; (2) is MDI group, and (3) is subcutaneous + oral treatment group

4. Discussion

The application of insulin pump treatment has a high initial acquisition cost and training needs [10]. Its economic effectiveness has not reached a consensus and is an important factor affecting the acceptance of insulin pump treatment in diabetic patients. cost-effectiveness analysis is an economic analysis method gradually applied in clinical practice, which can comprehensively analyze the treatment effect and cost of insulin pump for patients with type 2 diabetes [11], This study conducted a cost-effectiveness analysis of the effect and cost of perioperative insulin pump treatment in current clinical patients with type 2 diabetes, providing intuitive economic reference and treatment guidance for insulin pump treatment for medical staff and patients.

4.1. Analysis of the Treatment Effect of Insulin Pump Application in Patients with Perioperative Type 2 Diabetes Mellitus

4.1.1. Insulin Pump Treatment Has Shortened the Time to Reach the Blood Glucose Standard in Patients with Perioperative Type 2 Diabetes

At present, clinical diabetic patients regard insulin pump treatment as an option to increase the treatment cost, and the cost-effectiveness of insulin pump treatment needs to be certified and promoted urgently. The blood glucose time in CSII group in this study was 3.52 ± 2.94 days, which was lower than the 5.30 ± 3.53 days and 5.45 ± 4.85 days in MDI group and subcutaneous + oral treatment group, which was compared with Du Yaling. [12]. The CSII group blood glucose standard time is lower than the MDI group of consistent results, the possible reason is compared with the application of subcutaneous insulin injection before large dose and (or) bedtime injection long-acting insulin glucose treatment mode, insulin pump with basic quantity and large dose combined insulin secretion mode, not only can regulate the body caused by eating increased blood glucose, and can simulate insulin secretion in normal life, realize basic insulin infusion, and then achieve a smooth and rapid treatment of blood glucose. At the same time, perioperative patients use insulin pump targeted blood glucose management norms and standards [13], It is of great significance to provide more effective glucose management for patients with type 2 diabetes with perioperative glucose fluctuations. Although the clinical workers pay more attention to the evaluation of the effect of glucose control, the shorter the time is not the better, and the shorter time is related to the incidence of hypoglycemia.

4.1.2. Insulin Pump Treatment Reduces the Incidence of Postoperative Infection in Patients with Perioperative Type 2 Diabetes

The incidence of postoperative infection is an important indicator for perioperative patients to assess postoperative wound recovery and to meet the discharge criteria. Although type 2 diabetes patients perioperative blood glucose control situation and the correlation of the incidence of postoperative infection has been the attention of clinical surgery department doctors, but there are still some doctors and patients do not understand the working principle of insulin pump and glucose treatment effect, insulin pump treatment as patients with poor blood glucose control forced choice, the cost-effectiveness of insulin pump treatment has not been very good application. In this study, the incidence of postoperative infection in CSII patients (12.9%) was much lower than that in MDI patients (30.2%) and basically the same as that in subcutaneous + oral treatment patients (12.5%), including 6.3% in neurosurgical patients and 23.3% in urologic surgery, which does not comply with the distribution of postoperative infection incidence in the current clinical study. Existing clinical studies show that the incidence of postoperative wound infection in neurosurgical patients ranges from 7.69% to 23.08% [14]; The incidence of infection after urological wound is about 3% to 6% [15]. It may be because the patient's wound recovery requires a good humoral environment, and the body's leukocyte phagocytosis and wound healing rate will decrease significantly at blood glucose > 11.1 mmol/L, thus increasing the body's chance of infection and poor wound healing [16]. At the same time, a clear diagnostic criteria for the incidence of postoperative infection. In order to integrate the concept of the incidence of postoperative infection, the infection judgment index was defined as the body temperature at 5 d exceeds 38.5°C, or conventional blood white blood cells and neutral percentage exceeds normal value [17]. Infection diagnosed by the Clinical Diagnosis Standards for Hospital Infection (Trial) issued by the Ministry of Health in 2001 [18], The scope of the concept is more comprehensive, The incidence value of postoperative infection was expanded accordingly. Secondly, both patients in CSII group and MDI group in this study had indications for treatment with insulin pump. And subcutaneous + oral treatment group patients with blood glucose level is lower than CSII and MDI group blood glucose level, only subcutaneous injection of long-acting insulin combined with oral medication, can make blood glucose level to the standard level, subcutaneous + oral treatment group patients to recover the wound environment is better, may be the direct cause of the low incidence of postoperative infection.

4.2. Analysis of the Cost of Glucose Control Treatment in Patients with Perioperative Type 2 Diabetes Mellitus

However, both from the perspective of medical institutions and from the perspective of patients, the choice of perioperative patient glucose control regimen is largely affected by the treatment cost, and a large part of clinical medical staff and patients are still confused by the direct cost caused by insulin pump treatment. Indeed, perioperative patients treated with insulin pump cost no higher than patients with other glucose control regimens. Roze class. [19] By simulating the patient lifetime, it was found that the complication cost was 15% lower in the CSII group than in the MDI group. Yang Wei et al. [20] It is proposed that CSII can reduce the hospital stay, reduce the total hospitalization costs, and reduce the corresponding treatment costs. No consensus among existing studies on the economic effectiveness of applying insulin pump therapy. Meanwhile, the inclusion of cost indicators in the analysis is incorrect, which may cause the lower related cost of short-term treatment of MDI than that of CSII. The results of the analysis of this study showed that, Although the cost of glucose control was higher in the CSII group than in the MDI and subcutaneous + oral treatment groups, However, the integrated glucose control effect was better in the CSII group, By applying the cost-effectiveness analysis method for the analysis, The costs saved by the CSII, MDI, and subcutaneous + oral treatment groups were RMB 609.07 yuan, 343.83 yuan, and 311.25 yuan, respectively, The cost savings in CSII group were much more than those in MDI group and subcutaneous + oral treatment group; The cost saved by reducing the incidence of postoperative infection by 1 percentage point was 166.20 yuan, 60.34 yuan and 135.70 yuan, respectively, The cost savings were greater in the CSII group than in the MDI and subcutaneous + oral treatment groups. Comprehensive analysis shows that CSII has a good cost-effectiveness.

5. Conclusions

Perioperative type 2 diabetes patients with insulin pump have the shortest blood glucose standard time, low postoperative infection incidence, and has good treatment effect; perioperative type 2 diabetes patients have good cost-effectiveness. In conclusion, it is suggested that medical institutions are recommended to promote the application of insulin pump in patients with type 2 diabetes, help manage the blood glucose of type 2 diabetes patients, making the results more scientific and credible [12]. To improve patients' treatment compliance and treatment satisfaction, and to maximize patients' interests and the reasonable allocation of medical resources.

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