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ORIGINAL CONTRIBUTIONS

Preoperative Prediction of Type 2 Diabetes Remission After Gastric Bypass Surgery: a Comparison of DiaRem Scores and ABCD Scores

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Abstract
Background Gastric bypass surgery has been well accepted as a novel treatment modality for type 2 diabetes mellitus (T2DM) in obese patients. Some scoring systems have been proposed for the selection of T2DM patients who are eligible for gastric bypass surgery. This study compares two scoring systems with regard to remission of T2DM after gastric bypass surgery.
Methods This retrospective cohort study included 245 patients (150 females and 95 males) who had undergone gastric bypass surgery for the treatment of T2DM with 1 year follow-up. We examined the predictive power of complete remission of two scoring systems, the DiaRem score, and the ABCD score. The DiaRem score includes the factors of age, HbA1c, medication, and insulin usage. The ABCD score includes the factors of age, BMI, C-peptide level, and duration of T2DM. The rate of remission of T2DM after gastric bypass surgery was evaluated using both scoring systems.
Results At 1 year after surgery, the percent weight loss was 26.5 % and the mean BMI decreased from 35.7 to 26.2 kg/m^2. The mean HbA1c decreased from 8.8 to 6.2 %. A significant number of patients showed improvement in glycemic control, including 130 (53.1 %) patients with complete remission (HbA1c < 6.0 %), 36 (14.7 %) patients with partial remission (HbA1c < 6.5 %), and 26 (10.6 %) patients with improvement (HbA1c < 7 %). Both the DiaRem score and the ABCD score predicted the success of the gastric bypass surgery, but the ABCD score was better at differentiating patients with poorer score (27.9 vs. 9.1 %, $p < 0.001$).
Conclusions Gastric bypass surgery is a treatment option for obese T2DM patients. The ABCD score is better at predicting T2DM remission at 1 year after gastric bypass surgery than the DiaRem score.

Keywords Type 2 diabetes · Gastric bypass · Predictor · Remission

Type 2 diabetes mellitus (T2DM) is a chronic debilitating disease with potentially serious medical complications and socioeconomic effects [1]. Bariatric surgery is the most effective treatment for morbid obesity and has been proven successful in treating concomitant T2DM in morbidly obese patients (BMI > 35 kg/m^2) [2, 3]. Recently, bariatric surgery, especially the gastric bypass surgery, has been accepted as a treatment modality in combination with lifestyle change and medical therapy for T2DM in mildly obese patients with a BMI < 35 kg/m^2 and insufficient glycemic control [4, 5]. Several randomized trials have shown that gastric bypass surgery results in better glycemic control than medical treatment in T2DM patients with a BMI < 35 kg/m^2 [6–10]. Short-term results of remission of T2DM after gastric bypass surgery were reported to be more than 80 % in a meta-analysis paper [2]. However, the remission rate after gastric bypass was found to be 68.2 % when using a restrictive criteria for T2DM remission and 35.1 % of those experienced T2DM remission redeveloped diabetes within 5 years [11]. Other studies have also shown that some patients with T2DM

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remission after surgery have experienced recurrence of T2DM over time [12–14]. In addition, the remission rate might be even lower than 40 % in low BMI patients [15].

Because gastric bypass surgery is not a treatment without risk and carries long-term complications, we need to choose who are best to have T2DM remission after surgery is selected and patients who are predicted to have a poor outcome are excluded. Therefore, we need some scoring systems to help choosing and consulting the patients who are best suited for metabolic surgery in clinical practice, just like other scoring systems in many complex clinical problems. Hayes et al. proposed a model for predicting the resolution of type 2 diabetes in severely obese subjects following Roux-en Y gastric bypass surgery [16], and Ramos-Levi AM et al. designed a statistical model to predict type 2 diabetes remission after bariatric surgery [17]. However, these two studies are limited by the small number of included patients. Lee et al. proposed a diabetes surgical score (ABCD score) based on the results of a large prospective study [18]. This simple scoring system provides helpful and novel information for identifying the best candidates for metabolic surgery [19]. A probability score for preoperative prediction of T2DM remission following gastric bypass surgery was also proposed by Still et al. based on the examination of a large number of patients, and it includes the following factors: age, insulin use, HbA1c level, and type of anti-diabetic medication (DiaRem score) [20]. The DiaRem score had recently been validated externally [21]. Our goal was to examine these two scoring system for their preoperative predictive ability of T2DM remission after metabolic surgery.

Methods

Participants

In this retrospective study, we identified patients who were enrolled in a metabolic surgery program for T2DM treatment at Min-Sheng General Hospital Metabolic Surgery Institute between 2007 and 2013. The patients were eligible for metabolic surgery if they met the following criteria: T2DM diagnosis, age 18–67 years, and BMI greater than 24 kg/m^2. The exclusion criteria included the presence of end organ damage, pregnancy, and previous gastrointestinal surgery. Patients with type 1 diabetes or poor B-cell function were also excluded (i.e., diagnosis of type 1 diabetes, positive for antiGAD or islet cell auto-antibodies, fasting C-peptide levels <1 ng/ml, or unresponsive to a stimulus test). Anthropometric measures (BMI), blood pressure, and blood chemical data (fasting plasma glucose, glycated hemoglobin (HbA1c), serum insulin, and lipid profile) were measured at baseline and at annual follow-up. Diagnosis and classification of T2DM were based on a fasting plasma glucose concentrations ≧126 mg/dl or positive history of that and under the current use of antidiabetic medications [22]. Diabetes remission was defined as follows: complete remission, HbA1c <6.0 % without anti-diabetes medication for 1 year; prolonged remission, complete remission lasting 5 years; partial remission, HbA1c <6.5 % for at least 1 year without anti-diabetes medications; and improvement, HbA1c <7.0 % for at least 1 year [23].

This study was approved by the institutional review board of Min-Sheng General Hospital. All participants provided written informed consent.

Interventions

The surgical procedures performed included three types of gastric bypass procedures: laparoscopic Roux-en-Y gastric bypass (LRYGB), laparoscopic mini-gastric bypass (LMGB), and laparoscopic single anastomosis duodenojejunal bypass with sleeve gastrectomy (LSADJB-SG), which have all been published previously [24, 25]. In brief, LRYGB was performed by the antecolic and antegastric route with 100 cm of bilio-pancreatic limb and 100–200 cm of alimentary limb. LMGB was performed by creating a long-sleeved gastric tube over a 36Fr bougie along the lesser curvature from the antrum to the angle of His and a loop gastroenterostomy at 150–250-cm distal to the ligament of Trietz. The bypass limb was increased in super-morbid obese patients. LSADJB-SG was performed by creating a sleeve gastrectomy over a 36Fr bougie and leaving a 4 cm long antrum. The isoperistaltic end-to-side loop duodenojejunal anastomosis was performed at the intestine 150 to 250 cm to the ligament of Trietz. In this study, the efficacies of these three gastric bypass techniques were similar to those previously reported [25]. The type of operation performed is usually codecided by the patient and the surgeon after several comprehensive discussions based on reliable scientific criteria.

The DiaRem Score

The DiaRem score was produced by Christopher Still and colleagues to predict the probability of remission of type 2 diabetes after gastric bypass surgery [20]. The DiaRem score includes the factors of age, HbA1c, medication, and insulin usage. A 4-point score, ranging from 0 (lowest value) to 3 (maximal value), is used for the factors of age and HbA1c level. For other antidiabetes drugs, only a 3-point score was used. For insulin treatment, a 10-point score was used. The cutoff values for each of the four variables are shown in Table 1. The points for each variable were added, resulting in the final DiaRem score ranging from 0 to 22 points. Patients with lower scores were predicted to have a higher probability of T2DM remission after gastric bypass surgery.

Table 1 Calculation of DiaRem score for the probability of diabetes remission after metabolic surgery

Factor	Score
Age (years)	
<40	0
40–49	1
50–59	2
≥60	3
HbA1c (%)	
<6.5 %	0
6.5–6.9 %	2
7.0–8.9 %	4
≥9.0 %	6
Other diabetes drugs	
No sulfonylureas or insulin-sensitizing agents other than metformin	0
Sulfonylureas and insulin-sensitizing agents other than metformin	3
Treatment with insulin	
No	0
Yes	10
Total score calculated by adding each of the four variables	0–22

Table 2 Calculation of ABCD score for the probability of diabetes remission after metabolic surgery

Factor	Score
Age (years)	
<40	1
≥40	0
BMI (kg/m^2)	
<27	0
27–34.9	1
35–41.9	2
≥42	3
C-peptide (ng/ml)	
<2	0
2–2.9	1
3–3.9	2
≥5	3
Duration of DM (years)	
>8	0
4–8	1
1–3.9	2
<1	3
Total score calculated by adding each of the four variables	0–10

The Age, BMI, C-peptide, and Duration (ABCD) Score

The ABCD Diabetes Surgery Score system consisted of four variables—age, BMI, C-peptide level, and duration of diabetes—and was first reported by Wei-Jei Lee and colleagues [18]. A 4-point score ranging from 0 (lowest value) to 3 (maximal value) was used for BMI, C-peptide level, and duration of diabetes. For age, only a 1-point score was used. The cutoff values for each of the four variables are shown in Table 2 [19]. The points for each variable were added, resulting in the final ABCD score ranging from 0 to 10 points. Patients with higher ABCD scores were predicted to have a higher probability of T2DM remission after gastric bypass surgery.

Statistical Analyses

Statistical analyses were performed using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). Baseline comparisons were performed using chi-square tests, paired *t* tests, and one-way ANOVA. Continuous variables are expressed as the mean ± standard deviation. Differences in pertinent characteristics between patients who did and did not experience remission were established using the Mann-Whitney *U* test. We evaluated the remission rate according to the DiaRem and ABCD scores separately to assess the ability of both scoring systems to predict treatment success. A two-sided *p* value of 0.05 was considered statistically significant.

Results

Patients' Characteristics and Weight Loss After Surgery

Of the 754 T2DM patients who underwent primary gastrointestinal diversionary procedures between January 2007 and December 2013, three patients died during the study period and 196 (27.6 %) were lost to follow-up. The remaining 555 (72.0 %) patients with at least 1-year of follow-up were selected for further analysis. After exclusion of patients who underwent non-gastric bypass procedures or revision surgery or had an incomplete medication history, 245 patients were included in the analysis.

The preoperative clinical characteristics of the 245 T2DM patients are shown in Table 3. The mean age was 44.2 ± 10.4 years (range 18–70 years), and the mean BMI was 35.7 ± 7.8 kg/m^2 (range 24.1–59.0). The mean HbA1c level and disease duration were 8.8 ± 1.6 % (range 5.6–13.2) and 5.8 ± 5.0 years (range 0.1–26), respectively. One hundred twenty-five (51.0 %) patients underwent LRYGB, 62 (25.3 %) underwent LMGB, and the remaining 58 (23.7 %) underwent LSADJB-SG. There was no surgical mortality in this series. Eight patients (3.3 %) developed major complications within 30 days of postoperative period including leakage (3), bleeding (3), ulcer perforation (1), and respiratory failure (1), and 15 (6.1 %) patients developed minor complications.

Table 3 Comparison of clinical data before and after metabolic surgery

	Before ($n=245$)	After ($n=245$)	p value
Sex, F (%)	150 (61.2 %)		
Age, years	44.2 (10.4)		
Duration of DM history (years)	5.8 (5.0)		
Medication number	1.6 (0.9)	0.3 (0.6)	<0.001
Insulin usage (N)	65 (26.5 %)	4 (1.6 %)	<0.001
Weight (kg)	96.8 (22.5)	71.1 (13.6)	<0.001
BMI (kg/m^2)	35.7 (7.8)	26.2 (4.1)	<0.001
Waist (cm)	111.8 (15.4)	97.7 (8.4)	<0.001
Weight loss (%)		25.1 (8.7)	
SBP (mmHg)	140.1 (17.2)	125.9 (19.7)	<0.001
DBP (mmHg)	90.5 (12.3)	77.2 (14.2)	<0.001
FPG (mg/dl)	178.1 (65.6)	107.5 (36.0)	<0.001
HbA1C %	8.8 (1.6)	6.2 (1.1)	<0.001
C-peptide (ng/ml)	3.6 (2.0)	1.73 (0.8)	<0.001
Insulin (IU/l)	26.1 (41.1)	5.75 (5.6)	<0.001
HOMA	12.0 (21.7)	1.69 (2.0)	<0.001
Total cholesterol (mg/dl)	178.1 (65.6)	175.2 (35.8)	<0.001
Triglyceride (mg/dl)	251.6 (217.1)	105.2 (50.3)	<0.001
LDL (mg/dl)	114.1 (31.5)	106.2 (30.6)	0.003
AST (IU/L)	32.7 (27.6)	22.7 (13.9)	<0.001
ALT (IU/L)	45.4 (40.5)	24.9 (19.9)	<0.001

BMI body mass index, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *HDL-C* high density lipoprotein cholesterol

*$p<0.05$

At 1 year after surgery, the mean percent total body weight loss was 25.1 ± 8.7 % and the mean BMI was 26.2 ± 4.1 kg/m^2, and the mean HbA1C had decreased from 8.8 ± 1.6 to 6.2 ± 1.1 %. Accompanying metabolic parameters, such as fasting plasma glucose, blood lipid levels, liver enzymes, and blood pressure, had significantly improved (Table 3). Medication use was also significantly reduced. Figure 1 shows the weight change and HbA1c decrease over the 5 years after surgery.

Comparison of DiaRem Score and ABCD Score

A complete remission of T2DM was achieved in 130 (53.1 %) of the T2DM patients at the 1-year follow-up. Another 36 (14.7 %) patients achieved partial remission, and 26 (11.4 %) achieved improved status. Table 4 shows the comparison of the predictive abilities of the DiaRem score and the ABCD score for the

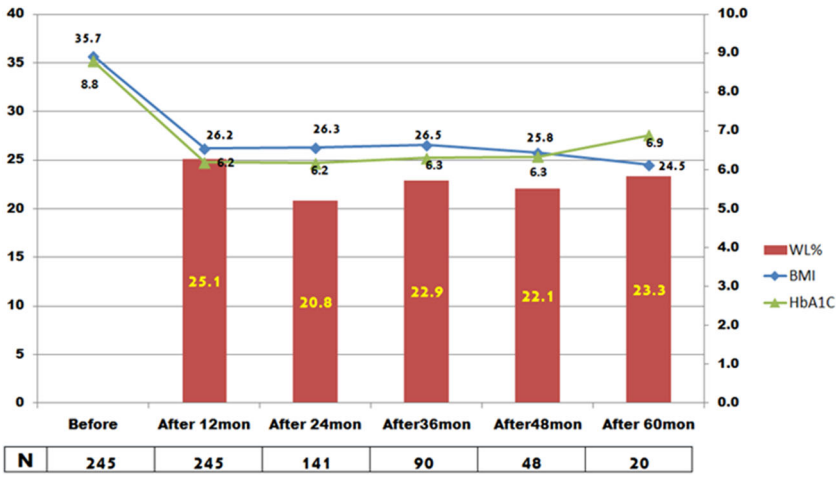

Fig. 1 BMI, weight loss%, and HbA1c changes of the study group

Table 4 Comparison of DiaRem score and ABCD score

DiaRem score				ABCD score			
Score	*N*	Remission *N*	Completed remission rate	Score	*N*	Remission *N*	Completed remission rate
0–2	5	5	100.0 %	10–9	12	12	100.0 %
3–7	68	58	85.3 %	8–7	44	39	88.6 %
8–12	108	47	43.5 %*	6–5	62	42	67.7 %*
13–17	21	8	38.1 %	4–3	83	33	39.8 %
18–22	43	12	27.9 %*	2–0	44	4	10.7 %*
Total	245	130	53.1 %	Total	245	130	53.1 %

*$p < 0.05$ between the subgroups of DiaRem and ABCD score

probability of diabetes remission after gastric bypass surgery. Patients with lower DiaRem scores had a higher success rate of T2DM remission (from 100 % with the lowest score to 27.9 % with the highest score). In contrast, patients with higher ABCD scores had a higher rate of T2DM remission (from 100 % with the highest score to 9.1 % with the lowest score). Both the DiaRem score and ABCD score predicted the success of metabolic surgery, but the ABCD score was better at differentiating patients with middle scores (43.5 vs. 67.7 %, $p < 0.05$) and poorer scores (27.9 vs. 9.1 %, $p < 0.05$).

Analyses of DiaRem Score and ABCD Score

The distributions of patients with different DiaRem scores and ABCD scores are shown in Table 5. The patient distribution was similar for the low DiaRem score and the high ABCD score. However, the patients with a high DiaRem score (bad prognosis) had wider ranging ABCD scores. Some patients with a high DiaRem score had a relatively high ABCD score. The T2DM remission rate in subgroups of the different clinical factors of both scores is shown in Table 6. There was a better correlation in the factors of ABCD score than in the DiaRem score.

Table 5 Distribution of patients in different DiaRem and ABCD score categories

ABCD score	DiaRem 0–2	DiaRem 3–7	DiaRem 8–12	DiaRem 13–17	DiaRem 18–22	Overall
10–9	1	11	0	0	0	12
8–7	3	22	14	3	1	44
6–5	1	18	35	2	6	62
4–3	0	15	36	10	22	83
2–0	0	2	22	6	14	44
Overall	5	68	107	21	43	245

Prediction of T2DM Remission Using ABCD Scoring System

The ABCD score is a predictor of complete and partial T2DM remission and improved T2DM status in T2DM patients after metabolic surgery (Table 7). There was very low chance of complete remission of T2DM in patients with an ABCD score

Table 6 T2DM remission rate for each factor of DiaRem and ABCD score

Factors		No.	Remission rate	*p* value
Age (years)	<40	84	60 (71.4 %)	<0.001*
	40–49	78	21 (26.9 %)	
	50–59	58	15 (25.9 %)	
	≥60	18	5 (27.8 %)	
HbA1c (%)	<6.5 %	8	6 (75.0 %)	0.004*
	6.5–6.9 %	19	15 (78.9 %)	
	7.0–8.9 %	115	66 (57.4 %)	
	≥9.0 %	100	41 (41.0 %)	
Other diabetes drugs	No	38	24 (63.2 %)	0.177
	Yes	201	103 (51.2 %)	
Treat with insulin	No	176	105 (59.7 %)	<0.001*
	Yes	59	19 (32.2 %)	
BMI (kg/m^2)	<27	27	2 (7.4 %)	<0.001*
	27–34.9	98	46 (46.9 %)	
	35–41.9	79	49 (62.0 %)	
	≥42	43	35 (81.4 %)	
C-peptide (ng/ml)	<2	42	8 (19.0 %)	<0.001*
	2–2.9	67	29 (43.3 %)	
	3−4.9	84	54 (64.3 %)	
	≥5	44	32 (72.7 %)	
Duration of DM (y)	≥8	76	19 (25.0 %)	<0.001*
	4−8	69	38 (55.1 %)	
	1−3.9	70	45 (64.3 %)	
	<1	29	27 (93.1 %)	

BMI body mass index

*$p < 0.05$

Table 7 T2DM remission rate for each ABCD score

ABCD score	Patient no.	Complete remission (HbA1c < 6.0 %)	Complete and partial remission (HbA1c <6.5 %)	Remission and improved (HbA1c <7 %)
0	2	0 (0.0 %)	1 (50 %)	1 (50 %)
1	14	1 (7.1 %)	3 (21.4 %)	6 (42.9 %)
2	28	3 (10.7 %)	8 (28.6 %)	12 (42.9 %)
3	41	16 (39.0 %)	22 (53.7 %)	27 (65.9 %)
4	42	17 (40.5 %)	25 (59.5 %)	32 (76.2 %)
5	29	19 (65.5 %)	25 (86.2 %)	28 (96.6 %)
6	33	23 (69.7 %)	30 (99.9 %)	31(93.9 %)
7	27	23 (85.2 %)	24 (88.9 %)	27 (100 %)
8	17	16 (94.1 %)	17 (100 %)	17 (100 %)
9	11	11 (100 %)	11 (100 %)	11 (100 %)
10	1	1 (100 %)	1 (100 %)	1 (100 %)
Overall	245	130 (53.1 %)	166 (67.8 %)	192 (78.4 %)

of ≤2. The rate of complete remission in patients with ABCD scores above 4 was greater than 60 %.

Discussion

In this report, we showed that both the DiaRem and ABCD scoring systems can predict the probability of diabetes remission after gastric bypass surgery. However, in patients with less favorable scores, the ABCD score is superior to the DiaRem score at predicting diabetes remission. In this study, the most favorable scores for both the ABCD and DiaRem scoring systems corresponded with 100 % diabetes remission; however, for the least favorable sores, the DiaRem score corresponded with 27.9 % diabetes remission, while the ABCD score corresponded with 9.1 % diabetes remission. A recent external validation study of the DiaRem scoring system by Ali Aminian and colleagues found that patients with the worst DiaRem score had a 20 % 5-year partial or complete remission rate, in contrast to the 2 % rate observed in the original study. This finding, in agreement with our finding, indicates that the DiaRem score was limited in the predictive ability of its poorer score.

The major limitation of the DiaRem score is the retrospective nature of the factors it includes and the lack of the most important predicting factor of diabetes remission, duration of T2DM. Duration of disease has been consistently recognized as the best predictor of T2DM remission after surgery, because it reflects the course of T2DM and the progressive deterioration of B-cell function [17, 20, 26–32]. The longer the duration of T2DM, the lower the probability of T2DM remission is. Other identified negative preoperative predictors of T2DM remission after metabolic surgery include old age, higher BMI, insulin usage, higher HbA1c level, lower C-peptide levels, and restrictive procedure [26–32].

The second limitation of the DiaRem score is that it was developed in a study cohort with mean BMI of 48.8 kg/m^2. This BMI is close to that of super-morbid obesity. Therefore, this group of patients is indicated for the bariatric surgery regardless of whether they have T2DM comorbidities. In other words, T2DM remission may not have been the treatment goal for this group of patients. The mean BMI of this study cohort was 36 kg/m^2, and all patients were seeking metabolic surgery for the treatment of diabetes. Therefore, the DiaRem score limited in its predictive ability of T2DM remission after metabolic surgery because the score was developed in a cohort of morbidly obese patients. Therefore, the ABCD is superior to the DiaRem score in evaluating the eligibility of patients for metabolic surgery.

This study has some limitations. The first limitation is the lack of different metabolic procedures. Because the DiaRem score was developed in patients who underwent gastric bypass procedure, we only included gastric bypass patients for the comparison of the DiaRem and ABCD scores in this study. We were unable to analyze the role of the ABCD score in predicting eligibility for different procedures in the current study. Another limitation of this study is the follow-up period. We only analyzed the outcome of our study at 1 year because the number of patients with long-term follow-up was limited. Long-term follow-up data to the extent of decades is necessary to fully understand the true efficacy of metabolic surgery in the treatment of this chronic, progressive disease. However, diabetes remission after metabolic surgery has been previously shown to be stable up to 5 years. The last limitation of this study is that it included a single institute and patients of a single ethnic group. Further studies with multiple sites and different races are necessary to confirm the clinical application of the ABCD score.

In conclusion, bariatric or gastrointestinal metabolic surgery is a promising treatment for insufficiently controlled

obesity-related T2DM. The ABCD scoring system, a simple multidimensional grading system, is better than the DiaRem scoring system for predicting T2DM remission at 1 year after metabolic surgery.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent For this type of study, formal consent is not required.

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