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Original article

Prediction of type 2 diabetes remission after metabolic surgery: a comparison of the individualized metabolic surgery score and the ABCD score

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Abstract

Background: Metabolic surgery has become increasingly accepted for the treatment of type 2 diabetes (T2D). However, there is limited evidence regarding the optimal candidate and surgical procedure. Although a new individualized metabolic surgery (IMS) score was recently proposed for procedure selection, it has yet to be validated.

Objective: To validate the IMS score with regard to remission of T2D after metabolic surgery and compare it with the age, body mass index, C-peptide level, and duration of T2D (ABCD) score.

Setting: Hospital-based bariatric center.

Methods: A total of 310 T2D patients who underwent gastric bypass and sleeve gastrectomy at an academic center in Taiwan and had a minimum 5-year follow-up (2004–2012) were examined for the predictive power of complete remission using the IMS and the ABCD scoring systems.

Results: At the 5-year follow-up, weight loss was 27.5%, with mean body mass index decreasing from 37.8 to 27.9 kg/m^2, mean glycated hemoglobin decreased from 8.6% to 6.1%, and prolonged remission of T2D achieved in 224 (72.3%) T2D patients. Remission rates were higher in patients who underwent gastric bypass than in those who underwent sleeve gastrectomy (73.6% versus 66.1%; $P = .04$), regardless of T2D severity, and were 96%, 68%, and 16% in patients with IMS mild, moderate, and severe scores, respectively. Although both scores predicted the success of surgery, the ABCD was better in patients with IMS moderate scores.

Conclusion: Metabolic surgery is an option for T2D patients with obesity. The ABCD score may be better at predicting T2D remission after metabolic surgery compared with the IMS score. (Surg Obes Relat Dis 2018;14:640–645.) © 2018 American Society for Metabolic and Bariatric Surgery. All rights reserved.

Keywords: Obesity; T2D; Sleeve gastrectomy; Gastric bypass; IMS score; ABCD score

Type 2 diabetes (T2D), fueled by the obesity epidemic, has emerged as a major health problem worldwide. It is a chronic, debilitating disease with potentially serious medical complications and socioeconomic effects [1,2]. Unfortunately, current medical treatments have been relatively unsatisfying, and less than half of patients are able to

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achieve their therapeutic goals [3]. Metabolic surgery, derived from bariatric surgery, has now been proposed for the treatment of obese T2D patients. Several randomized trials reported that metabolic surgery results in better glycemic control compared with medical and lifestyle interventions in T2D patients with obesity [4–9]. Therefore, metabolic surgery, especially gastric bypass (GB), has recently been endorsed as a treatment modality, in combination with lifestyle changes and medical therapy, for these patients [10,11]. However, the remission rates after metabolic surgery varied widely among studies due to different definitions of remission, patient characteristics, type of surgery, and length of follow-up. In addition, other studies reported that some patients with T2D remission after surgery developed recurrence of T2D over time [12–14]. Because metabolic surgery is not risk free and carries long-term complications, we need to select appropriate candidates and exclude those with predicted poor outcomes to increase the chances of T2D remission in patients after surgery. Accordingly, in clinical practice, we need predictors or scoring systems to help guide patient selection.

Several scoring systems have been previously proposed; however, they were limited by the small number of patients included [15,16]. Lee et al. [17] proposed a diabetes surgical age, body mass index (BMI), C-peptide level, and duration of T2D (ABCD) score based on the results of a large prospective study. This simple scoring system provides helpful and novel information for identifying the best candidates for metabolic surgery [18]. Another score for the preoperative prediction of T2D remission, the DiaRem score, was proposed by Still et al. [19] based on examination of a large number of patients undergoing GB. The DiaRem score variables include age, insulin use, glycated hemoglobin (HbA1C) level, and type of antidiabetic medication. However, it is limited in in differentiating patients with severe disease [20,21]. Recently, an individualized metabolic surgery (IMS) score based on a large patient cohort with long-term follow-up was proposed and validated [22]. In addition to candidate selection, this IMS score can be applied to procedure selection for metabolic surgery. Our goal was to validate this score in a different ethnic group and compare the IMS and ABCD scoring systems with regard to their preoperative predictive ability of T2D remission after metabolic surgery.

Methods

The institutional review board approved this retrospective study. We identified patients who were enrolled in a metabolic surgery program for T2D treatment at Min-Sheng General Hospital Metabolic Surgery Institute between 2004 and 2012. During this period, 670 patients with T2D underwent metabolic surgery. Patients with complete baseline and postoperative follow-up of at least 5 years were included. Patients who had revision surgery and those who were lost to follow-up were excluded. Notably, 66 patients had been enrolled in previous randomized trials [23,24]. Finally, a total of 310 patients composed the study population. The complete follow-up rate was 46.3% (310/670).

The aim of the study was to validate the IMS score. The same inclusion and exclusion criteria were applied: long-term diabetes remission was defined by HbA1C $<6.5\%$, fasting blood glucose <126 mg/dL, and no diabetes medications for at least 5 years according to the American Diabetes Association consensus statement [25].

Additionally, the predictive power of the IMS score was compared with that of the ABCD score after the same criteria.

Interventions

The surgical procedures performed included laparoscopic sleeve gastrectomy (SG) and 2 types of GB procedures: laparoscopic Roux-en-Y gastric bypass (RYGB) and single-anastomosis (mini-) GB (SAGB) [26]. RYGB was performed through the antecolic and antegastric routes with 100 cm of biliopancreatic limb and 100 to 200 cm of alimentary limb. SAGB was performed by creating a long-sleeved gastric tube over a 36-Fr bougie along the lesser curvature from the antrum to the angle of His and a loop gastroenterostomy at 150 to 250 cm distal to the ligament of Trietz. For SG, the stomach was completely mobilized before vertical transection of the stomach was accomplished with 5 to 6 firings of a 60-mm linear stapler guided by an orogastric tube (size 36 Fr) placed along the lesser curvature for calibration. After gastric resection, the long gastric remnant stapler line was invaginated with a 3–0 vicryl suture to prevent leakage and hemorrhage [27]. Both the patient and the surgeon decided the type of operation after several comprehensive seminars with the multidisciplinary team. All procedures were performed using the laparoscopic technique.

The IMS score

The IMS score was produced by Aminiam et al. [22] to predict the probability of remission of T2D after SG and RYGB. The IMS score variables include the number of preoperative diabetes medications, insulin use, duration of diabetes, and HbA1C levels. A nomogram, which generates the IMS score based on the 4 variables was constructed, allowed for the classification of diabetes severity into mild, moderate, and severe groups. Patients with milder severity are predicted to have a higher probability of T2D remission after metabolic surgery.

The ABCD score

The ABCD diabetes surgery score system comprises 4 variables, including age, BMI, C-peptide level, and duration

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

Variable	Points on ABCD index gastric bypass *P* value			
	0	1	2	3
Age	≥40	<40		
BMI, kg/m^2	<27	27–34.9	35–41.9	>42
C-peptide, ng/L	<2	2–2.9	3–4.9	>5
Duration of diabetes, yr	>8	4–8	1–3.9	<1

ABCD = age, body mass index, C-peptide level, and duration of type 2 diabetes; BMI = body mass index.
The total possible values range from 0 to 10.
The cutoff values for the assignment of points are shown for each variable.

of diabetes, and was first reported by Lee et al. [17] A 4-point score ranging from 0 (lowest value) to 3 (maximum value) is used for BMI, C-peptide level, and duration of diabetes, while a 1-point score is used for age. The points for each variable are added, resulting in the final ABCD score ranging from 0 to 10 points. Patients with higher ABCD scores are predicted to have a higher probability of T2D remission after metabolic surgery. The cut-off values for each of the 4 variables are shown in Table 1 [18].

Statistical analyses

Statistical analyses were performed using SPSS version 18.0 (SPSS Inc., Chicago, IL). Baseline comparisons were performed using χ^2 tests, paired *t* tests, and one-way analysis of variance. Continuous variables were expressed as a mean ± standard deviation. Differences in pertinent characteristics between patients who did and did not achieve remission were established using the Mann-Whitney *U* test. We calculated the remission rates according to the IMS and ABCD scores separately to assess the ability of both scoring systems to predict treatment success. A 2-sided *P* value of .05 was considered statistically significant.

Results

Patient characteristics and change after surgery

The data set included 310 patients who underwent either GB (RYGB in 125 patients and SAGB in 120) or SG with a complete follow-up of at least 5 years. Baseline characteristics of the study cohorts are summarized in Table 2. Patients had a mean BMI of 37.8 ± 7.6 kg/m^2 (range, 24.1–59.0), a median duration of T2D of 3.6 ± 4.4 years (range, .1–26), and HbA1C of 8.6 ± 1.8% (range, 5.6–13.2). Average number of diabetes medications at baseline was 1.2 ± .9, with 42 (16%) patients receiving insulin treatment. There was no surgical mortality in this series. In total, 8 patients (2.5%) developed major complications within 30 days after surgery, while 15 (4.8%) developed minor complications.

Table 2
Comparison of clinical data of 310 patients before and after metabolic surgery

	Preoperative	5 yr after	*P* value
Female (%)	196 (63)		
Age, yr	40.1 (11.1)		
Duration of T2D, yr	3.6 (4.4)		
SG/RYGB/SAGB	56/111/143		
Medication number	1.23 (.9)	.25 (.6)	<.001*
Insulin usage, n	42 (13%)	9 (3%)	<.001*
Weight, kg	103.4 (24.2)	73.8 (15.6)	<.001*
BMI, kg/m^2	37.8 (7.6)	27.9 (7.1)	<.001*
Waist, cm	115.3 (18.2)	86.9 (15.3)	<.001*
Weight loss, %		27.5 (11.1)	
SBP, mm Hg	138.0 (17.1)	122.3 (17.4)	<.001*
DBP, mm Hg	86.4 (13.7)	74.2 (10.7)	<.001*
FPG, mg/dL)	175.5 (72.1)	103.2 (31.9)	<.001*
HbA1C, %	8.6 (1.8)	6.1 (1.0)	<.001*
C-peptide, ng/mL	4.4 (2.6)	1.5 (.6)	<.001*
Insulin, IU/L	27.3 (39.5)	5.6 (6.1)	<.001*
HOMA	11.6 (8.5)	1.21 (.9)	<.001*
Total cholesterol, mg/dL	199.1 (46.2)	167.8 (36.0)	<.001*
Triglyceride, mg/dL	253.3 (290.5)	97.3 (63.9)	<.001*
LDL, mg/dL	126.4 (38.4)	97.2 (30.3)	<.001*
AST, IU/L	39.3 (33.4)	27.7 (42.5)	.094
ALT IU/L	58.8 (53.7)	25.2 (38.1)	<.001*

T2D = type 2 diabetes; BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; FPG = fasting plasma glucose; HbA1C = glycated hemoglobin; HOMA = homeostasis model assessment; LDL = low-density lipoprotein; AST = aspartate aminotransferase; ALT = alanine aminotransferase.
*$P < .05$.

At the 5-year follow-up, the mean percent total weight loss was 27.5 ± 11.1% with the mean BMI dropping to 27.9 ± 7.1 kg/m^2 and the mean HbA1C decreasing from 8.6 ± 1.8% to 6.1 ± 1.0%. The accompanying metabolic parameters, including fasting plasma glucose, blood lipid levels, liver enzymes, and blood pressure, significantly improved (Table 2). In addition, the number of medications used was significantly reduced from 1.2 ± .9 to .23 ± .6 with 9 (3%) patients requiring insulin treatment.

Prolonged remission of T2D was achieved in 224 (72.3%) patients at the 5-year follow-up. The remission rate was higher in patients undergoing GB than those undergoing SG; however, the difference was statistically insignificant (74% versus 66%; *P* = .253) regardless of T2D severity.

Validation of IMS score

Applying the IMS score to this cohort resulted in the following classification: 30% mild, 62% moderate, and 8% severe. Prolonged T2D remission rates were 95.7% for the mild, 68.4% for the moderate, and 16% for the severe group. Table 3 demonstrates the 5-year remission rates after GB and SG according to the severity of T2D. In patients with mild T2D, GB was associated with a 96.5% and SG with an 85.7% remission rate, which is compatible with the

Table 3
Comparison of IMS score and ABCD score

Original report (Cleveland & Spain*)				Validation cohort (MSGH)		
Severity level	Frequency	Remission after GB	Remission after SG	Frequency	Remission after GB	Remission after SG
Mild	15% (14%*)	92% (91%*)	74% (91%*)	31%	96%	86%
Moderate	51% (62%*)	60% (70%*)	25% (56%*)	62%	69%	66%
Severe	34% (24%*)	12% (8%*)	12% (3%*)	7%	17%	0%
Total		49% (64%*)	28%(52%*)		74%	66%

IMS score = individualized metabolic surgery score; ABCD score = age, body mass index, C-peptide level, and duration of type 2 diabetes; MSGH = Min-Sheng General Hospital; GB = gastric bypass procedures; SG = sleeve gastrectomy.

*Percentage reported in training and validated cohort of original paper [18].

92% and 74% remission rates of GB and SG, respectively, in the original report. In patients with moderate T2D, long-term remission was observed in 69% of the GB and 66% of the SG group. Both GB and SG were less effective in patients with severe T2D with 0% remission rate in the SG and 17.4% in the GB groups. The predictive power of IMS score for T2D remission after SG or GB was similar to the original report.

Comparison of IMS score and ABCD score

The distribution of the studied patients with different IMS scores and ABCD scores is shown in Table 4. Using the IMS score, the majority of patients (62%) were classified as moderate, 30% were classified as mild, and only 8% were classified as severe. The patients were more uniformly distributed using the ABCD score compared with the IMS score. In addition, patients with mild and moderate IMS scores had wider distributions when classified using the ABCD score.

Table 5 shows a comparison of the predictive ability of the IMS score for the probability of T2D remission after SG and GB. GB produced a higher rate of T2D remission than SG in patients with mild and severe IMS scores (96% versus 86% and 17% versus 0%, respectively). However, there was no difference in remission rates between the SG and GB groups in patients with moderate IMS scores (69% versus 66%). In contrast, the ABCD score was better at differentiating patients with different remission rates after SG and GB (Table 6). In patients with moderate ABCD scores (6–5 and 0–2), GB produced a higher T2D remission rate than SG (84% versus 67%, $P = .036$; 18% versus 0%, $P = .012$). There was a very low probability of complete remission of T2D in patients with an ABCD score <2. The rate of complete remission in patients with ABCD scores >4 was $>50\%$.

Table 4
Distribution of patients in different IMS Score and ABCD score categories

ABCD score	IMS Mild	IMS Moderate	IMS Severe	Overall
10–9	46	12	0	58
8–7	32	52	1	85
6–5	11	53	1	65
4–3	3	60	8	71
2–0	0	16	15	31
Overall	92	193	25	310

IMS score = individualized metabolic surgery score; ABCD score = age, body mass index, C-peptide level, and duration of type 2 diabetes.

Discussion

In this report, we validated the usefulness of the IMS score in predicting the probability of T2D remission after metabolic surgery. To the best of our knowledge, our study is the first to validate the IMS score in a different ethnic cohort (Asian). The probability of long-term T2D remission was 96%, 68%, and 16% for patients with IMS scores of mild, moderate, and severe, respectively. Thus, T2D patients may be selected for metabolic surgery according to their IMS scores. However, this study demonstrated a limited differentiating power between SG and GB in patients with moderate IMS scores (66% versus 69%). On the contrary, GB produced persistently better T2D remission rates compared to SG in all patients using the ABCD score. In addition, the 73.9% overall remission rate of this study is also higher than the 44.4% overall remission rate in the original IMS score report [22]. This may be explained by the different patient characteristics in both studies. Patients included in this study had a lower BMI (37.8

Table 5
Comparison of 5-year T2D remission rate of SG and GB at different IMS score

SG			GB		
SCORE	N	Remission N (%)	N	Remission N (%)	*P* value
Mild	7	6 (86%) (74%) (91%)*	85	82 (96%) (92%) (91%)*	<.001*
Moderate	47	31 (66%) (25%) (50%)*	146	101 (69%) (60%) (71%)*	.720
Severe	2	0 (.0%) (12%) (3%)*	23	4 (17%) (12%) (8%)*	.050*
Total	56	37 (66%) (28%) (52%)*	254	187 (74%)	.253

T2D = type 2 diabetes; SG = sleeve gastrectomy; GB= gastric bypass procedures; IMS score = individualized metabolic surgery score.

*Percentage reported in training and validated cohort of original paper [22].

Table 6
Comparison of 5-year T2D remission rate of SG and GB at different ABCD score

	SG		GB		
SCORE	N	Remission N (%)	N	Remission N (%)	*P* value
10–9	7	6 (86)	51	50 (98)	.229
8–7	21	17 (81)	64	59 (92)	.215
6–5	15	10 (67)	50	42 (84)	.036*
4–3	10	4 (40)	61	31 (51)	.735
2–0	3	0 (0)	28	5 (18)	.012*
Total	56	37 (66)	254	187 (74)	.253

T2D = type 2 diabetes; SG = sleeve gastrectomy; GB = gastric bypass procedures; ABCD score = age, body mass index, C-peptide level, and duration of type 2 diabetes score.
*$P < .05$.

versus 46.4 kg/m^2), younger median age (40 versus 51 yr), and shorter duration of T2D (3.6 versus 5.6 yr) compared with those included in the original IMS report.

The major limitation of the IMS score is the lack of a C-peptide value, which is considered the most important predicting factor, as most patients did not have this test performed before surgery. C-peptide is a peptide connected to insulin and is secreted simultaneously with insulin. Although insulin and C-peptide levels have similar indications, measuring insulin levels directly may be difficult due to hepatic clearance or in patients receiving insulin therapy. Many studies have reported that fasting C-peptide level is an important predictor of T2D remission because it may reflect an intact pancreatic reserve for insulin in T2D patients [6,28–35]. Therefore, C-peptide as a surrogate of insulin and pancreatic β-cell mass should be included in the preoperative evaluation of metabolic surgery. After C-peptide level measurement, the ABCD and IMS scores can be used to evaluate patients more accurately before their selection for metabolic surgery.

The second limitation of the IMS score is that it was developed in a study cohort of patients with a mean BMI of 46.4 kg/m^2, which is considered morbid obesity and an indication for bariatric surgery regardless of T2D status. Therefore, T2D remission may not be an appropriate primary endpoint for bariatric surgery in this group of patients. In contrast, the mean BMI of patients included in this study was 37.8 kg/m^2 and the primary endpoint was T2D treatment remission because those patients were seeking metabolic surgery for T2D treatment. Therefore, the IMS score was limited in predicting T2D remission after metabolic surgery because it was initially evaluated in a cohort of patients with morbid obesity, while the ABCD score evaluated patients specifically seeking metabolic surgery for treatment of T2D.

GB surgery produced superior T2D remission rates in patients with better control of their T2D compared with SG using both the IMS and the ABCD. However, the mechanisms underlying GB's superior efficacy remain controversial. The efficacies of both GB techniques (RYGB and SAGB) for T2D remission were previously found to be similar [36]. In addition, patients in both GB groups had similar weight loss at 5 years and were able to avoid regaining the weight. In contrast, patients who underwent SG failed to achieve similar results in terms of controlling their diabetes. SG surgery is considered in T2D patients with quick increases in postprandial GLP-1 (Glucagon-like peptide-1) and PYY (Peptide YY) due to rapid bowel transit time [37]. Conversely, GB surgery bypasses the duodenum and proximal jejunum, which is believed to play an important role in reducing insulin resistance and diabetes control [38]. The duodenum and upper intestine play an important role in glycemic control due to the effect of incretins. T2D patients have diminished incretin effects, which may be due to the overproduction of anti-incretins; thus, they can be treated by bypassing the duodenum [39]. Although specific human anti-incretins have not yet been found, decretin is a strong candidate that was recently identified in an animal model [40]. Another study comparing SG and RYGB identified some duodenal factors that are possibly related to duodenal exclusion, supporting the duodenal exclusion theory [41]. In addition, the duodenal-jejunal bypass sleeve or liner, a recently developed device, was reported to have a similar effect on glycemic control in humans, which provides additional support to the duodenal exclusion theory [42]. Therefore, although SG is currently the first option in bariatric surgery, GB may be a more optimal option for the treatment of T2D.

This study was limited by its single institution setting and a patient population of a single ethnic group. Hence, further studies in multiple sites and with different ethnicities are necessary to compare the clinical applications of the ABCD and IMS scores. However, we recommend adding C-peptide measurement to the ABCD and IMS scores in the assessment of T2D patients before the choice of metabolic surgery to predict outcomes more accurately.

Conclusions

Metabolic surgery is a well-known and promising treatment indicated for insufficiently controlled T2D in patients with obesity. The ABCD scoring system may be better at predicting metabolic responses after bariatric surgery in patients with moderate T2D.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

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