

# Do Bariatric Surgery-Related Type 2 Diabetes Remission Predictors Add Clinical Value? A Study on Asian Indian Obese Diabetics

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## Abstract

**Background** Bariatric surgery has emerged to be the most effective treatment strategy for the treatment of obesity and type 2 diabetes mellitus (T2DM) achieving high remission rates. Many factors have been evaluated with a potential to predict the improvement of glycemic control following bariatric procedures. This study aims to study the various predictive factors for T2DM and the ABCD score in obese diabetic patients undergoing bariatric surgery in a South Indian population.

**Methods** A total of 53 obese patients (BMI > 30 k/m<sup>2</sup>) with T2DM who underwent laparoscopic sleeve gastrectomy (LSG) and laparoscopic gastric bypass (LGB) from March 2014 to March 2015 were selected for the study. The patients were followed up to study the effects of various predictors of T2DM remission at 1 year.

**Results** Out of the 53 patients, 35 (66%) underwent LSG and 18 (34%) underwent LGB. Patients (81.1%) had T2DM remission. Mean HbA1c values decreased from 8.07 ± 1.98 to 6.0 ± 0.71. Only higher pre-operative body weight ( $p = 0.04$ ) and lower HbA1c level ( $p = 0.04$ ) were significantly associated with T2DM remission. Higher absolute weight loss ( $p = 0.03$ ) after surgery was also significantly associated with T2DM remission. ABCD score was not significantly associated with T2DM remission although patients with ABCD score higher than 7 demonstrated 100% remission rate.

**Conclusion** Among all the factors, only higher pre-operative weight and better glycaemic control along with better post-operative weight loss were significantly associated with the remission of T2DM. Although not significantly associated with remission of T2DM, higher ABCD scores had higher likelihood of remission.

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## Introduction

Obesity has a strong association to the development of type 2 diabetes mellitus (T2DM). The prevalence of both obesity and T2DM is on a rise contributing to considerable morbidity and mortality [1, 2]. Obesity is seen to coexist with 44% of T2DM, 23% of ischemic heart disease and 7–41% of cancers, globally [3]. Bariatric surgery has emerged to be the most effective treatment strategy for obesity and T2DM achieving high remission rates [4].

Although there is a remarkable improvement in glycaemic control of obese diabetic patients undergoing bariatric surgery, this improvement has not been consistent with some patients

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having better outcomes compared to others. Many factors have been evaluated with a potential to predict the improvement of glycaemic control following bariatric procedures. These include age, body mass index, duration and severity of diabetes, C-peptide levels and medication usage [2].

In an attempt to create a robust predictive model, various scoring systems have been proposed, using different combinations of the factors mentioned above. This includes the DiaRem score [5], DSS score [6] and the ABCD score [7]. ABCD score is one popular score, proposed by Lee et al., whose predictions are based on four factors including age, body mass index, C-peptide and duration of T2DM. Scores can range from 0 to 10 with higher scores predicting higher remission rates [7].

We aimed to study the possible associations of various preoperative patient characteristics and its relationship to the resolution of T2DM following metabolic surgery in our subset of South Indian patients. We also aimed to evaluate the applicability of the ABCD score in our population.

## Methods

After the Institutional review board (IRB) approval, we performed a retrospective evaluation from a prospectively collected database of all patients who underwent bariatric surgery (BMI > 30 kg/m<sup>2</sup> and T2DM) from March 2014 to March 2015 and completed follow up of at least 12 months. Diagnosis and classification of T2DM was based on criteria established by the American Diabetes Association [8]. Exclusion criteria were presence of end organ damage, redoing of bariatric procedures and those patients who were missed during follow up. Remission of T2DM was defined as attainment of HbA1c level <6.5% without use of oral hypoglycaemic drugs or insulin. The primary outcome measure was identification of factors predicting T2DM remission. Secondary outcome measures were to assess the applicability of ABCD score [9] and to compare the outcomes among the surgical procedures.

ABCD score uses a four-point scale, ranging from 0 (minimal value) to 3 (maximal value) for BMI, C-peptide and duration of diabetes. For age, the score has a two-point value from 0 to 1. Points for each variable are added and a total score is calculated which ranges from 0 to 10 points (Table 1).

All patients were subjected to complete evaluation on outpatient basis in accordance with institutional protocols and were admitted a day prior to surgery. Patients' body weight was measured in light clothing without shoes to the nearest 0.1 kg, and body height was measured to the nearest 0.1 cm. BMI was calculated as weight in kilograms divided by height in metres squared. Blood was drawn for laboratory examination from an antecubital vein following an overnight fast. All specimens were stored at -30 °C and processed within 24 h of collection.

**Table 1** Modified ABCD score

Variable	Modified ABCD score			
	0	1	2	3
Age (years)	<40	>40		
BMI	<27	27–34.9	35–41.9	>42
C-peptide	<2	2–2.9	3–4.9	>5
T2DM duration	>8	4–8	1–4	<1

Total score is calculated by adding scores for each of the parameters. Scores range from 0 to 10

Two types of surgeries were performed: laparoscopic sleeve gastrectomy (LSG) and laparoscopic gastric bypass (LGB). LSG was performed using a standard 36 Fr gastric calibration tube. LGB was performed creating a gastric pouch of 25–30 ml, alimentary limb of 125 cm and biliopancreatic limb of 75 cm. All procedures were performed by the same surgical team. Patients underwent LSG or LGB after thorough preoperative workup and counselling by a multidisciplinary team keeping in mind individual patient factors like need for long-term nutritional supplementation and others. Patients finally made an informed decision regarding which procedure to undergo.

## Statistical Analysis

Continuous variables with a normal distribution are expressed as mean ± standard deviation (SD). Variables with a non-normal distribution like duration of diabetes are reported as medians with range. Categorical variables are expressed with the use of frequencies. We used Chi-square test for categorical variables, while Student's paired *t* test was used for continuous data, to compare the study groups. A *p* value of 0.05 was considered statistically significant. Variables with (*p* = 0.1) were further subjected to linear and logistic regression analysis. Statistical analyses were performed using SPSS version 23.0 (IBM Corp. N.Y.).

## Results

### Patient Demographics

A total of 60 patients underwent metabolic surgery during the study period, of which 7 were excluded for not completing 1 year of follow up. The baseline characteristics of 53 patients who were included in the analysis are shown in Table 2. Mean age was 45.86 ± 11.69 years. Sex ratio was almost equal. Mean BMI and mean body weight were 43.25 ± 7.4 kg/m<sup>2</sup> and 113.85 ± 22.45 kg respectively. Mean C-peptide levels and mean glycosylated haemoglobin (HbA1c) levels were 2.95 ± 0.99 ng/ml and

**Table 2** Comparison of baseline characteristics LSG group with LGB group

S no.	Characteristics	Total (n = 53)	LSG group (n = 35)	LGB group (n = 18)	p value
1	Age (years)	45.86 ± 11.69	43.94 ± 11.41	49.61 ± 11.64	0.95
2	Gender	26 (49.1%)	16	10	0.56
	Male	27 (50.9%)	19	8	
	Female				
3	BMI (kg/m <sup>2</sup> )	43.25 ± 7.4	43.64 ± 6.8	42.49 ± 8.57	0.59
4	Weight (kg)	113.85 ± 22.45	115.37 ± 20.5	110.89 ± 26.1	0.49
5	C-peptide levels (ng/ml)	2.95 ± 0.99	3.15 ± 1.09	2.57 ± 0.63	0.04 <sup>a</sup>
6	HbA1c levels (%)	8.07 ± 1.98	7.85 ± 2.04	8.5 ± 1.84	0.25
7	T2DM duration (years)	3 (0–40)	4.42 ± 7.37	6.94 ± 5.92	0.21
8	Pre op medication usage	1(0–6)	1.28 ± 1.2	0.66 ± 1.18	0.08
	HA(tablets per day)	7 ± 17.24	3.22 ± 14.47	12.44 ± 20.06	0.06
	Insulin (units per day)	(range 0–80)			

LSG laparoscopic sleeve gastrectomy, LGB laparoscopic gastric bypass, BMI body mass index, HbA1c glycosylated haemoglobin, T2DM type 2 diabetes mellitus, OHA oral hypoglycaemic agents

<sup>a</sup> Statistically significant

8.07 ± 1.98% respectively. Median duration of T2DM was 3 years (range, 0–40 years). Median number of preoperative oral hypoglycaemic tablets per day was 1 (range, 0–6 tablets). Mean units of insulin usage was 7 ± 17.24 units per day.

Among the total group of 53 patients, 35 (66%) underwent LSG and 18 (34%) underwent LGB. As seen in Table 2, there was no significant difference between the LSG group and the LGB group with respect to preoperative characteristics including age, body mass index, HbA1c levels, body weight, duration of T2DM and medication usage except for preoperative C-peptide levels which were significantly lower ( $p = 0.04$ ) in the LGB group.

At 1 year after surgery, mean weight and mean body mass index decreased to 80.84 ± 15.43 kg and 30.72 ± 5.1 respectively. Mean HbA1c levels decreased to 6.0 ± 0.71 (Table 3). All these levels were significantly improved compared to their preoperative values ( $p < 0.0001$ ).

### Comparison of Postoperative Characteristics

Table 4 shows the comparison of postoperative characteristics between the LSG and LGB groups. There was no significant difference between the two groups with respect to postoperative BMI, decrease in BMI, body weight, weight loss, HbA1c levels and decrease in HbA1c levels.

### Comparison of Characteristics Stratified by T2DM Remission

Forty-three (81.1%) out of 53 patients achieved remission of T2DM. Table 5 shows the comparison of characteristics between remission and the non-remission group. There was no significant difference in age, preoperative body mass index,

preoperative C-peptide levels, duration of T2DM and decrease in body mass index between remission and non-remission groups. But, a statistically significant difference was observed in two preoperative parameters, which were body weight ( $p = 0.04$ ) and HbA1c levels ( $p = 0.04$ ). Absolute weight loss following surgery was also significantly higher in the remission group ( $p = 0.03$ ).

### Correlation of ABCD Score with Remission

Table 6 shows the correlation of ABCD score with remission. Higher scores showed higher likelihood of remission with scores >7 consistently showing 100% remission rate. But, on multivariate analysis by logistic regression, the resolution of diabetes (HbA1c < 6.5) could not achieve statistical significance with ABCD score, irrespective for subcategorization or individual values ( $p = 0.15$ ). On performing a logistic regression analysis for the LSG and LGB groups separately, with respect to T2DM remission, neither the component variables nor the ABCD score as a whole showed significance in either of the groups (LSG group:  $p = 0.28$ ; LGB group:  $p = 0.30$  for ABCD score).

### Discussion

The ability to predict diabetes remission after metabolic surgery assists in both, selection of cases as well as selection of the type of procedure to be performed. The understanding on this allows the patient, in conjunction with the multidisciplinary bariatric team, to take an informed decision. Accordingly, three predictive scoring systems for T2DM remission have

**Table 3** Improvement in parameters following surgery

S no.	Characteristics	Pre op	Post op	P value
1.	Weight (kg)	113.85 ± 22.45	80.84 ± 15.43	<0.0001 <sup>a</sup>
2	BMI (kg/m <sup>2</sup> )	43.25 ± 7.40	30.72 ± 5.1	<0.0001 <sup>a</sup>
3	HbA1c (%)	8.07 ± 1.98	6.0 ± 0.71	<0.0001 <sup>a</sup>
4	OHA usage (tablets per day)	1.07 ± 1.25	0.22 ± 0.60	<0.0001 <sup>a</sup>
5	Insulin usage (units per day)	7.03 ± 17.24	0.84 ± 3.69	0.01 <sup>a</sup>

BMI body mass index, HbA1c glycosylated haemoglobin, OHA oral hypoglycaemic agents

<sup>a</sup> statistically significant

been published, namely ABCD score [7], DiaRem score [5] and DRS score [6]. We aimed to study the various predictive factors individually and the applicability of the ABCD scores in our patient population.

Age has been evaluated as a predictor of T2DM remission as age reflects the general reserve of beta cell function which gradually decreases with increasing age [7]. It has been shown that younger age is not only associated with more successful weight loss after bariatric surgery but also with higher remission rate of T2DM [10–12]. Hamza et al. have reported that with each additional 12 years of age, the chance of T2DM remission is reduced by 20% [10]. Lakdawala et al. noted that patients above 60 years of age had a significantly poorer outcome [13]. In our study, patients with remission were relatively younger with patients less than 40 years having a 90% likelihood of remission, although this difference was not statistically significant.

BMI is also considered to be a predictor of T2DM remission on the basis of quantification of the degree of obesity and also the degree of insulin resistance. Contrary to this belief, Mingrone et al. showed that baseline BMI was unrelated to T2DM remission in morbidly obese patients [14]. Panunzi et al. also reported similar findings [15]. Wang et al., in their meta-analysis, found baseline BMI to play a role in T2DM remission only in Asian population and not in non-Asian population [12]. However, our study which included only Asian Indian patients showed that baseline BMI was not a statistically significant predictive factor for T2DM remission. But, the role of BMI continues to be debatable as many studies

have shown that patients with higher preoperative BMI have higher T2DM remission rates. Dixon et al. also found that a BMI >35 kg/m<sup>2</sup> is a predictive factor for T2DM remission in a Korean population [16]. Robert et al. noted that at 1 year following bariatric surgery, a BMI less than 35 is a positive predictive factor for T2DM remission [17].

Remission of T2DM following bariatric surgery depends on baseline beta cell function [2]. Hence, higher C-peptide which is a proxy marker for estimating pancreatic beta cell mass and function level has been shown to be associated with higher diabetes remission rate, particularly in Asian population [12]. Lee et al. have shown a correlation of preoperative C-peptide with T2DM remission rate. Preoperative C-peptide levels of <3, 3–6 and >6 ng/ml was associated with 55.3, 82.0 and 90.3% remission of T2DM respectively, in morbidly obese patients [18]. Dixon et al. have shown that a C-peptide level of >2.9 ng/ml is a predictor of T2DM remission [16]. Lakdawalla et al. reported a fasting C-peptide level of more than or equal to 3 nmol/l to be a predictor of T2DM remission [13]. We, however, did not find any statistical difference in preoperative C-peptide levels between the remission and non-remission group.

T2DM is a progressive disease characterized by progressive beta cell failure over the years [19]. Thus, the longer the duration of disease, the lower should be the chance of remission following bariatric surgery. However, there is little agreement on the cut-off value which ranges from 4 to 8 years among various studies [16, 17, 20]. Lee et al. noted that patients with T2DM

**Table 4** Comparison of postoperative characteristics LSG group with LGB group

S no.	Post op characteristics	LSG (n = 35)	LGB (n = 18)	P value
1	BMI (kg/m <sup>2</sup> )	31.42 ± 4.97	29.36 ± 5.47	0.17
2	HbA1c (%)	6.01 ± 0.66	6.00 ± 0.83	0.95
3	Weight (kg)	82.97 ± 15.05	76.69 ± 15.73	0.16
4	Decrease in HbA1c levels	1.84 ± 2.17	2.50 ± 1.76	0.27
5	Decrease in BMI (kg/m <sup>2</sup> )	12.21 ± 4.49	13.13 ± 4.84	0.49
6	Weight loss (kg)	32.42 ± 12.32	34.16 ± 13.89	0.64

LSG laparoscopic sleeve gastrectomy, LGB laparoscopic gastric bypass, BMI body mass index, HbA1c glycosylated haemoglobin, OHA oral hypoglycaemic agents

**Table 5** Comparison of characteristics between remission and non-remission group

S no.	Characteristics	Remission (HbA1c < 6.5) (N = 43)	Non-remission (HbA1c > 6.5) (N = 10)	P value
1	Age (years)	45.16 ± 11.50	48.9 ± 12.67	0.3
2	Pre op BMI (kg/m <sup>2</sup> )	43.54 ± 7.31	41.99 ± 8.02	0.5
3	C-peptide (ng/ml)	2.98 ± 1.04	2.82 ± 0.74	0.6
4	T2DM duration (years)	5.05 ± 7.22	6.30 ± 5.92	0.61
5	Pre op weight (kg)	116.72 ± 22.23	101.5 ± 19.94	0.04 <sup>a</sup>
6	Pre op HbA1c (%)	7.81 ± 1.9	9.2 ± 1.99	0.04 <sup>a</sup>
7	Change in BMI (kg/m <sup>2</sup> )	13.03 ± 4.37	10.53 ± 5.11	0.09
8	Weight loss (kg)	34.83 ± 12.0	25.20 ± 13.65	0.03 <sup>a</sup>

BMI body mass index, HbA1c glycosylated haemoglobin, T2DM type 2 diabetes mellitus, OHA oral hypoglycaemic agents

<sup>a</sup> Statistically significant

duration of less than 4 years had a higher remission rate than did those with more than 8 years of duration [4, 18, 21]. Lakdawala et al. reported a 100% remission rate for T2DM in patients with less than 5 years of duration as compared to a remission rate of 60–75% for a duration of 5–15 years [13]. Rosenthal et al. also noted that remission rates for patients with duration of more than 5 years were considerably lower after sleeve gastrectomy [22]. We too noted better T2DM outcomes in patients with shorter duration of T2DM, which was, however, not statistically significant.

Elevated HbA1c is a marker of poor glycaemic control. Chronic hyperglycaemia leads on to glucotoxicity to pancreatic beta cells leading to their apoptosis and overall beta cell decline [23]. Lower preoperative HbA1c has been associated with a higher diabetes

remission rate following bariatric surgery [20, 24–26] with a high preoperative HbA1c being the strongest predictor of postoperative insulin requirement [27]. In a study of T2DM patients undergoing LGB, strict preoperative glycaemic control was associated with a 58% higher chance of remission [28]. In a recent meta-analysis of 1149 T2DM patients, Wang et al. concluded that T2DM patients who had lower HbA1c levels had higher remission rates [12]. Robert et al. found lower baseline HbA1c levels to be associated with higher chance of T2DM resolution irrespective of the type of bariatric surgery performed [17]. In our study, preoperative HbA1c level was significantly associated with T2DM remission. Patients who had lower HbA1c levels had a significantly higher rate of T2DM remission.

One of the factors which we also evaluated was preoperative baseline body weight. We noted that the body weight of patients who underwent remission was significantly higher than those who did not undergo remission. Postoperatively, absolute weight loss was significantly associated with remission rates. Lee et al. have also shown higher weight loss to be associated with better T2DM remission rate [9]. Amelioration of insulin resistance by weight loss is considered to be one of the important mechanisms for diabetes resolution following bariatric surgery [29, 30]. Nannipieri et al. also noted improved insulin sensitivity in proportion to weight loss [31]. Our result of higher weight loss being associated with higher T2DM remission rate can also be explained based on improved insulin sensitivity. With the debate on weight-dependent and weight-independent mechanisms' contribution to T2DM still ongoing, our findings favour the weight-dependent theory with preoperative weight and absolute weightless being the major predicting factors.

Lee et al. proposed the Diabetes Surgery Score (also known as the ABCD score). This score has four domains including age, baseline BMI, preoperative C-peptide

**Table 6** Correlation of ABCD score with T2DM remission

Surgery	Remission (HbA1c < 6.5)	Non-remission (HbA1c > 6.5)	Total	% remission	
LSG	ABCD 1–5	6	3	9	66.6
	6, 7	18	4	22	75
	>7	4	0	4	100
	Total	28	7	35	
LGB	ABCD 1–5	9	2	11	81.8
	6, 7	4	1	5	80
	>7	2	0	2	100
	Total	15	3	18	
Total	ABCD 1–5	15	5	20	75
	6, 7	22	5	27	81.5
	>7	6	0	6	100
	Total	43	10	53	

LSG laparoscopic sleeve gastrectomy, LGB laparoscopic gastric bypass, HbA1c glycosylated haemoglobin, T2DM type 2 diabetes mellitus

levels and duration of T2DM. They validated this scoring system for predicting T2DM remission following both LSG and LGB. In ABCD score, values range from 0 to 10 with higher scores predicting better T2DM remission rates. Values of more than 7 has demonstrated 100% remission rate with a 1 point increase in ABCD score translating to 6.7% increase in remission rate [7, 32]. They also showed that ABCD score had good predictive value for patients undergoing metabolic surgery with a BMI of less than 30 [9]. We chose to study this score as this has been well validated in the Asian population. We noted a higher likelihood of remission with higher scores. Interestingly, even patients with relatively lower scores also showed good remission rates. This reflects that there could be additional factors, not incorporated in ABCD score, which might be playing an important role in remission. We also noted scores more than 7 showing a very high remission rate, signifying that scores above 7 have a higher predictive value for remission. This association however did not stand on logistic regression analysis, where ABCD score did not achieve statistical significance in predicting remission of T2DM. This may be due a relatively small sample size of our study.

We achieved an excellent remission rate of more than 80% in our patients. This could have been influenced by more stringent patient selection and relatively younger age. We also compared the outcomes of LSG and LGB in terms of T2DM remission. Decrease in HbA1c levels was higher in the LGB group in comparison to the LSG group, but the difference did not reach statistical significance. However, many studies have shown higher T2DM remission rates in the LGB group compared to the LSG group [33, 34]. There was also no difference in postoperative outcomes with respect to weight loss in our study. The logistic regression analysis too did not find any strength of association between T2DM remission and type of procedure performed. But, it should be noted that the groups were not comparable in terms of baseline C-peptide level which was significantly higher in the LSG group.

## Conclusion

Bariatric surgery is the most effective treatment modality for the treatment of obesity and T2DM. Various factors have been evaluated to predict T2DM remission following bariatric surgery. Our study favours the weight-dependent theory of T2DM remission with higher preoperative weight and higher weight loss being the major predictors of T2DM remission. Also, higher preoperative HbA1c level was noted to be negatively associated with T2DM remission. Higher ABCD scores, especially scores more than 7, have a higher likelihood of T2DM remission.

## Compliance with Ethical Standards

**Grant Information** No funding was received.

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

**Ethical Approval** For this type of study, formal consent is not required.

**Consent** Consent does not apply to our study.

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