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Predictive Markers for Diabetes Remission Post-Bariatric Surgery at King Abdulaziz Medical City in Jeddah: A Retrospective Cohort Study

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Abstract

Background

The global prevalence of type 2 diabetes mellitus (T2DM) is escalating, attributed to increasing obesity rates. The obesity and diabetes-related mortality rates in Saudi Arabia are among the highest worldwide. Bariatric surgery (BS), originally a weight-loss procedure, is now recognized by the American Diabetes Association and International Diabetes Federation as an effective treatment for T2DM, yielding greater efficacy in achieving remission than lifestyle and pharmacological interventions. BS enhances glycemic regulation by decreasing calorie consumption, improving insulin sensitivity, and increasing insulin secretion. This study evaluated the influence of BS on glycemic metrics and diabetic remission.

Methods

This retrospective cohort study was conducted within the Endocrine and General Surgery departments of King Abdulaziz Medical City in Jeddah. A total of 41 individuals with T2DM who underwent BS were selected using non-probability sequential sampling. Data were collected using the electronic record system BESTCare 2.0 and analyzed using JMP Pro 18.

Results

The cohort exhibited a mean age of 47.6 years and a preoperative body mass index (BMI) of 42.9 kg/m², with 70.7% undergoing sleeve gastrectomy. Postoperative results demonstrated substantial decreases in weight (112.9 kg to 78.9 kg), BMI (42.9 to 30.0 kg/m²), and HbA1c (8.0% to 5.9%), as well as enhancements in fasting glucose and lipid profiles. Diabetes remission was observed in 56.1% of cases within 6 months and was substantially associated with younger age, shorter diabetes duration, and the absence of insulin use at baseline.

Conclusion

In conclusion, BS markedly enhances glycemic regulation, weight-related parameters, and lipid profiles, with high rates of diabetes remission within 6 months of surgery. These findings highlight the necessity for early intervention and community awareness regarding BS as a treatment for T2DM. Subsequent studies should investigate predictive biomarkers using longitudinal designs.

Introduction

Diabetes mellitus is a chronic, progressive condition that imposes a significant burden on patients, the healthcare system, and the community [1]. The incidence of type 2 diabetes mellitus (T2DM) is rising worldwide due to increasing overweight and obesity rates [2]. In comparison with other member states

of the Gulf Cooperation Council (GCC), Saudi Arabia shows the highest incidence of diabetes-related mortality. Furthermore, Saudi Arabia exhibits an overweight and obesity prevalence rate of 35.4%, which is among the highest worldwide; the country ranks 14th in the World Health Organization's most recent data [3]. Given the known correlation between obesity and T2DM and the significant financial commitments and adverse health effects associated with these conditions, it is imperative to acknowledge the optimal strategies for addressing them [4].

The American Diabetes Association (ADA) acknowledged bariatric surgery (BS) as a viable treatment option for individuals with obesity and diabetes in 2009, despite its initial development for weight loss purposes. In 2011, the International Diabetes Foundation (IDF) recognized the potential of BS as a viable treatment option for individuals with obesity and T2DM. The specific physiological roles of gastrointestinal hormones in the surgical remission of diabetes are currently not well understood. However, BS is increasingly recognized as an effective approach for the treatment of T2DM and obesity, supported by randomized controlled trials demonstrating its superiority over lifestyle modifications and medical interventions [5–7]. Diabetic remission (DR) is defined as the complete discontinuation of medication with HbA1c < 6.5% or metformin monotherapy with HbA1c < 6.0% [8]. Vidal et al. [9] examined the effects of glucagon-like peptide-1 (GLP-1) on diabetes remission, revealing that additional mechanisms, namely caloric intake limitation, heightened insulin production, improved insulin sensitivity, and impaired nutrient absorption, play a significant role in remission [8, 10]. A multicenter trial demonstrated that tirzepatide reduces HbA1c and body weight to a greater extent than other drugs and achieved remission rates of 66–81% over 52 weeks, depending on the dose [11].

Positive correlation factors include being male and having shorter diabetes duration; furthermore, patients with tightly controlled HbA1C levels are more likely to achieve remission post-surgery [12, 13]. Negative correlations have been observed between T2DM remission and several factors, including elevated baseline HbA1c, decreased C-peptide levels, preoperative insulin use, prolonged diabetes duration, and inadequate weight loss [12, 14].

There has been a notable rise in the number of individuals diagnosed with diabetes and obesity worldwide, including within the population of Saudi Arabia. Several local studies have examined diabetes remission in the Kingdom of Saudi Arabia [3, 5, 7], yielding promising results. Diabetes and obesity demonstrate a substantial association with increased morbidity and mortality rates. Given the widespread demand for BS, this study examined the impact of BS on glycemic markers and evaluated its efficacy in achieving diabetes remission.

Methods

This retrospective cohort study involved individuals with T2DM who underwent BS from February 2021 to February 2023 at King Abdulaziz Medical City (KAMC), Jeddah, a center serving a substantial patient population in the western region of the Kingdom. All patients were registered with their identification and assigned medical record numbers in the BESTCare system 2.0, operated by the Ministry of National

Guard-Health Affairs (MNGHA) at KAMC. IRB approval for this study was obtained from King Abdullah International Medical Research Center (KAIMRC), a global institution for biomedical and clinical research. Study participants were required to be at least 18 years of age with a diagnosis of T2DM and a minimum follow-up duration of 6 months after surgery. Participants under 18 years of age and those with type 1 diabetes, inadequate medical documentation, and unconfirmed HbA1c readings were excluded.

All patients who met the predefined inclusion and exclusion criteria were included in the study sample, selected using a non-probability consecutive sampling technique. The data extraction technique was executed by the research team at MNGHA in Jeddah, Saudi Arabia, using a secure data collection spreadsheet created in Excel. The principal investigator was responsible for supervising the process. To achieve this purpose, the BESTCare system 2.0 was implemented. The preoperative parameters documented included demographic information (age and sex), anthropometric measurements (height, weight, and body mass index), duration of diabetes mellitus and medication, type of surgery, and comorbidities. Pre- and postoperative laboratory tests included HbA1c, fasting blood glucose, fasting insulin, fasting C-peptide, and fasting lipid profile.

All T2DM patients who met the criteria and underwent any of the following procedures were included: gastric bypass (Roux-en-Y gastric bypass), sleeve gastrectomy (gastric sleeve), biliopancreatic diversion with duodenal switch (BPD/DS), and adjustable gastric band (lap-band). The American Diabetes Association (ADA) and the International Diabetes Federation (IDF) set forth criteria to define remission as the cessation glucose-lowering drug (GLD) consumption with HbA1c levels < 48 mmol/mol (< 6.5%) during the postoperative follow-up period that was sustained for at least 3 months for those who met the inclusion and exclusion criteria [15, 16].

The data are presented as means and standard deviations (SDs) for continuous variables (height, weight, and body mass index [BMI]). Categorical variables (age and sex) are described using percentages. Chi-square or Fisher's exact tests were employed to compare categorical data. Statistical tests were used to assess the relationships between continuous and categorical variables, including the independent-samples *t* test, the Mann–Whitney U test, and one-way analysis of variance (ANOVA). A *p* value below 0.05 was considered to indicate significance. The statistical analysis was conducted using JMP Pro 14, developed by SAS Institute Inc. (Cary, NC, 1989–2019).

Results

The study comprised 41 individuals with T2DM who underwent BS at KCMC in Jeddah; 27 females (65.8%) and 14 males (34.2%), with a mean age of 47.6 ± 9.7 years. The mean duration of diabetes before surgery was 10.2 ± 7.6 years. Preoperatively, the average weight was 112.9 ± 19.4 kg, and the average BMI was 42.9 ± 6.5 kg/m²; 30 patients (73.2%) had a BMI ≥ 40 kg/m², and 11 (26.8%) had a BMI < 40 kg/m². The median follow-up time was 1.0 year (interquartile range [IQR] 1.0–2.5 years).

Post-surgery, total weight reduced to 78.9 ± 15.9 kg, and the mean BMI decreased to 30.0 ± 5.9 kg/m², reflecting an overall weight loss of 34.2 ± 13.8 kg, corresponding to approximately 30.3% of preoperative total body weight.

Diabetes remission was observed in 23 patients (56.1%) at a median of 6.0 (IQR 5.0–9.0 months) postoperatively. An evaluation of clinical and biochemical markers revealed substantial metabolic improvements. The mean HbA1c levels diminished from 7.9 ± 1.6% to 5.9 ± 1.1% ($p = 0.001$), and the mean FBG reduced from 9.9 ± 4.9 mmol/L to 6.1 ± 1.9 mmol/L ($p = 0.001$). Notable enhancements were recorded in lipid parameters; specifically, an elevation in HDL cholesterol (1.1 ± 0.2 mmol/L to 1.2 ± 0.3 mmol/L, $p = 0.047$) and a decrease in triglyceride levels (1.7 ± 0.9 mmol/L to 1.1 ± 0.6 mmol/L, $p = 0.001$). Total cholesterol, LDL cholesterol, and serum creatinine exhibited no significant alterations.

Patients were categorized as remitters or non-remitters, and the predictors of diabetes remission were investigated. Significant disparities were observed between the two groups. Patients attaining remission were younger (44.0 ± 8.3 years *vs.* 52.2 ± 9.5 years, $p = 0.005$) and had a shorter diabetes history (7.8 ± 6.2 years *vs*. 12.4 ± 8.1 years; 75.0% had < 10 years duration *vs.* 25.0%, $p = 0.048$). Preoperative insulin use was a detrimental predictor of remission, with only 39.1% of insulin users attaining remission versus 77.8% of non-insulin users ($p = 0.013$).

Likewise, the number of preoperative medications was associated with remission status. In patients receiving two or fewer antidiabetic drugs preoperatively, 78.3% attained remission, whereas only 27.8% of those on more than two medications achieved the same outcome ($p = 0.001$). No significant differences were observed between the two groups regarding BMI category (< 40 *vs*. ≥40 kg/m², $p = 0.556$) or type of BS (sleeve *vs.* bypass, $p = 0.613$).

Discussion

This retrospective cohort study examined prognostic markers for T2DM remission after BS in patients at King Abdulaziz Medical City in Jeddah. Our findings significantly strengthen the existing evidence supporting BS as an effective treatment for T2DM, achieving a remission rate of 56.1% within a median of 6 months postoperatively. This finding is consistent with the local outcome reported by Alnajjar et al., in which 48.5% of patients achieved complete remission following BS [3]. Similarly, a multicenter study by Honarmand et al. in Ontario, Canada, demonstrated a postoperative remission rate of 37% at the one-year follow-up [17]. Identifying demographic, clinical, and biochemical markers of remission provides critical insights that enhance patient selection and inform personalized treatment approaches.

Age and diabetes duration were among the strongest variables identified and were substantially correlated with remission outcomes. Patients who attained remission were significantly younger (44.0 ± 8.3 years) than non-remitters (52.2 ± 9.5 years), and a shorter duration of diabetes (< 10 years) provided a significant benefit (remission rate of 75.0% *vs.* 40.0%, $p = 0.048$). These findings validate the established understanding of the gradual deterioration in beta-cell function over time, underscoring the need for early surgical intervention. DeFronzo et al. [18] highlighted the pathophysiological irreversibility

of chronic T2DM, which aligns with our findings that underline the time-sensitive efficacy of surgical intervention.

Weight loss has been identified as a significant modifiable factor associated with remission. Mean weight loss was significantly higher in patients who attained remission (36.0 kg) than in those who did not (29.6 kg; $p = 0.017$). Although both groups exhibited significant reductions, the remission group exhibited a greater decrease in BMI and absolute weight, potentially suggesting improved insulin sensitivity and glycemic control. This observation aligns with results from the STAMPEDE trial [19], which showed greater diabetic remission in individuals who underwent extensive surgical intervention and achieved significant weight loss, underscoring the therapeutic synergy between metabolic surgery and weight reduction.

Sleeve gastrectomy was the primary surgical approach in our group, comprising 70.7%; Roux-en-Y gastric bypass accounted for 29.3%. In contrast to the findings of previous studies indicating superior glycemic improvement with bypass surgeries [19, 20], we observed no significant difference in remission rates between the two groups ($p = 0.613$). This disparity may be attributable to institutional protocols, preoperative optimization, and rigorous postoperative follow-up, as proposed in the LABS study [21]. Consequently, both methods may yield similar remission outcomes when used applied to suitably selected individuals with robust support systems. The relatively small sample size may also explain why no difference was found between the two interventions.

Biochemically, notable decreases in HbA1c (from 7.9 ± 1.6% to 5.9 ± 1.1%, $p < 0.001$) and fasting blood glucose (from 9.9 ± 4.9 mmol/L to 6.1 ± 1.9 mmol/L, $p < 0.001$) were observed postoperatively, indicating substantial enhancement in glycemic regulation. Moreover, HDL levels increased significantly ($p = 0.047$), whereas triglyceride levels decreased ($p = 0.001$), indicating a beneficial alteration in the cardiometabolic risk profile. These results align with those reported by Abdel-Rahman et al., who showed analogous improvements in glycemic and lipid profiles in a comparable Saudi demographic [22]. Our findings collectively highlight that BS both induces remission and provides substantial additional metabolic benefits.

An additional mechanism that may partially explain the observed glycemic improvement and diabetes mellitus remission post-BS is increased secretion of incretin hormones, such as GLP-1 and glucose-dependent insulinotropic polypeptide (GIP). Metabolic procedures such as Roux-en-Y gastric bypass and sleeve gastrectomy promote nutrient delivery to the distal intestine, leading to increased postprandial incretin release, the suppression of inappropriate glucagon secretion, improved glucose-dependent insulin secretion, and enhanced satiety, as described by Holst and Madsbad [23]. Supportive evidence for the main role of incretin signaling is further explained by the findings of recent clinical trials evaluating dual GLP-1/GIP receptor agonists, such as tirzepatide (SURPASS-1 trial; Rosenstock et al.), in which 81–86% of participants achieved HbA1c ≤ 6.5% and 31–52% reached HbA1c < 5.7% at 40 weeks [24].

Significantly, insulin use and the number of antidiabetic agents were adverse predictors of remission. Patients not using insulin before surgery exhibited a markedly higher remission rate (77.8% *vs.* 39.1%, *p*

= 0.013). In contrast, those on fewer than two diabetic drugs achieved a remission rate of 78.3%, compared with 27.8% among those on more than two prescriptions (p = 0.001). These observations align with the findings of a Danish population-based cohort study by Madsen et al. [8], which revealed reduced medication reliance as a significant clinical indicator of sustained remission.

The findings indicate that younger patients with a brief disease duration, reduced baseline pharmacologic burden, and non-insulin-dependent diabetes are ideal candidates for attaining remission by BS. This study's findings contribute to the current literature by corroborating these relationships within a Middle Eastern sample and further substantiate the case for prompt surgical referral and personalized risk stratification.

Limitations and Future Research

Our study had several limitations, notably its retrospective design and the restricted sample size. Moreover, the single-center design may limit the generalizability of our findings. Subsequent research with larger, multicenter populations and prolonged follow-up durations is required to substantiate the validity of these results. Moreover, additional research into factors such as genetic predisposition and inflammatory markers may yield a more profound understanding of the mechanisms underlying diabetes remission following BS. Future research should expand the assessment of remission to GLP1 agonists, not just B, given the significant weight loss and improvements in metabolic parameters with GLP1-related agents.

Conclusion

In this study, patients who achieved diabetes remission post-BS showed notable improvements in weight-related metrics, glycemic control, and lipid profiles compared with non-remitters, underscoring the importance of early intervention and effective care. These findings underscore the necessity for community awareness and education regarding the importance of BS in the management of T2DM. Future research should prioritize longitudinal studies to investigate predictive markers for remission and integrate advanced biochemical and genetic analyses to improve the reliability and generalizability of these results.

Declarations

Trial registration:

Not applicable. This study was a retrospective cohort study and did not involve a clinical trial.

Ethics declaration:

Ethical approval for this study was obtained from the King Abdullah International Medical Research Center (KAIMRC), Jeddah, Saudi Arabia. The study was conducted in accordance with institutional

ethical standards and the Declaration of Helsinki.

Ethics approval and consent to participate:

Ethical approval was obtained from the King Abdullah International Medical Research Center (KAIMRC), Jeddah, Saudi Arabia. Due to the retrospective nature of the study, the requirement for informed consent was waived by the Institutional Review Board.

Consent for publication:

Not applicable.

Competing interests:

The authors declare that they have no competing interests.

Author contributions:

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by the authors. All authors reviewed and approved the final manuscript.

Data Availability:

The datasets generated and/or analysed during the current study are not publicly available due to patient confidentiality and institutional data protection policies but are available from the corresponding author on reasonable request.

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Tables

Table 1 Baseline participant characteristics:

Variable	N = 41
Sex	
Female	27 (65.8)
Male	14 (34.2)
Age at surgery	47.6 ± 9.7
BMI pre-surgery	42.9 ± 6.5
Below 40	11 (26.8)
40 and above	30 (73.2)
BMI post-surgery	30.0 ± 5.9
Weight pre-surgery	112.9 ± 19.4
Weight post-surgery	78.9 ± 15.9
Total weight loss	34.2 ± 13.8
Duration of DM (years)	10.2 ± 7.6
Clinical variations	
Metformin	30 (73.2)
Sulfonylureas	8 (20.0)
DDP-Inhibitor	9 (21.9)
GLP-1 Receptor Agonist	7 (17.5)
SGLT2 Inhibitor	4 (9.6)
Basal insulin	21 (51.2)
Prandial insulin	19 (46.3)
Type of bariatric surgery	
Bypass	12 (29.3)
Sleeve	29 (70.7)
Length of follow up (years)	1.0 (1.0-2.5)
Remission	
No	18 (43.9)
Yes	23 (56.1)
Time to remission (months)	6.0 (5.0–9.0)

Number of medications pre-surgery	2.0 (2.0–3.0)
Number of medications post-surgery	0.5 (0–2.0)
Total insulin doses pre-surgery	39.7 ± 8.4
Total insulin doses post-surgery	12.2 ± 3.5

Table 2 Parameter changes pre- and post-surgery:

Parameter	**Pre-surgery**	**Post-surgery**	***p* value**
LDL	2.9 ± 1.3	2.9 ± 1.4	0.988
HDL	1.1 ± 0.2	1.2 ± 0.3	0.047
Triglyceride	1.7 ± 0.9	1.1 ± 0.6	0.001
Total cholesterol	4.7 ± 1.1	4.5 ± 1.3	0.485
Creatinine	75.8 ± 5.3	73.8 ± 12.2	0.847
HbA1c	7.9 ± 1.6	5.9 ± 1.1	0.001
Fasting Blood Glucose	9.9 ± 4.9	6.1 ± 1.9	0.001
Total insulin doses	39.7 ± 8.4	12.2 ± 3.5	0.001
Total weight loss (Kg)	36.0	29.6	0.017

Table 3 Factors associated with diabetes remission:

Factor	No Remission	Remission	*p* value
Age	52.2 ± 9.5	44.0 ± 8.3	0.005
BMI			0.556
Below 40	4 (36.4)	7 (63.6)	
40 and above	14 (46.7)	16 (53.3)	
DM Duration			0.048
Fewer than 10 years	4 (25.0)	12 (75.0)	
10 years and above	9 (60.0)	6 (40.0)	
Insulin use pre-surgery			0.013
No	4 (22.2)	14 (77.8)	
Yes	14 (60.9)	9 (39.1)	
HbA1c pre-surgery	7.5± 1.5	8.3± 1.7	0.141
HbA1c post-surgery	6.8 ± 0.9	5.2 ± 0.5	0.001
FBG post-surgery	7.6 ± 1.9	5.1 ± 1.0	0.001
Total weight loss (Kg)	36.0	29.6	0.017
Length of follow-up	1.8 ± 0.4	2.2 ± 0.5	0.537
Comorbidities			0.951
None	3 (42.9)	4 (57.1)	
At least one	15 (44.1)	19 (55.9)	
Type of bariatric surgery			0.613
Bypass	6 (50.0)	6 (50.0)	
Sleeve	12 (41.4)	17 (58.6)	
Number of medications pre-surgery			0.001
Two or fewer	5 (21.7)	18 (78.3)	
More than two	13 (72.2)	5 (27.8)	
Medications post-surgery			0.001
None	3 (15.0)	17 (85.0)	
At least one	15 (75.0)	5 (25.0)	