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Original Article

Diabetic Markers, Five Years after Bariatric Surgery

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Abstract
Background: Bariatric surgery delivers substantial weight loss for obese patients with comorbidities like diabetes mellitus. We aimed to investigate the impacts of bariatric surgery on diabetic markers after 5 years of follow-up.
Methods: This is a retrospective study on patients with diabetes and a history of bariatric surgery between 2016-2017. The diabetic markers before and 5 years following surgery, including a lipid profile, glucose level, and the required antidiabetic medications, were evaluated.
Results: 34 consecutive patients were included, 30 (88.2%) women, with a mean age of 52.71 ± 8.53 years. The majority (65%) of surgeries were Roux-en-Y gastric bypass (RYGB), and the remaining were one anastomosis gastric bypass (OAGB) and sleeve gastrectomy (SG). The serum levels of diabetic markers reduced during follow-up (P = 0.001), except for high-density lipoprotein levels and serum total cholesterol, which increased (P = 0.011, P = 0.838). Low-density lipoprotein levels reduced, but it was insignificant (P = 0.194). Surgery types had affected the changes of diabetic markers (P > 0.05). Demand for oral medication was reduced significantly, but insulin injection reduction was not significant (P = 0.006 and P = 0.099, respectively).
Conclusion: Our study showed favorable bariatric surgery results on patients with diabetes in long-term follow-up. However, dyslipidemia is still a concern.
Keywords: Bariatric surgery, Diabetes mellitus, Morbid obesity, R-Y gastric bypass, Sleeve gastrectomy, One anastomosis single bypass
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Introduction

Type 2 diabetes mellitus (T2DM) is associated with obesity. While more than 60% of patients with diabetes are obese, weight loss is attractive.[1,2] Additionally, T2DM is heterogeneous and progressive,[3] and often, a combination of two or more interventions is needed for controlling diabetes.[4] Intensifying treatment could induce weight gain. So, managing obese diabetic patients requires careful consideration.[5,6] Also, dietary regimens alone cannot reduce long-term weight loss due to the low adherence of patients to modified lifestyle efforts during the time.[7,8] This highlights the role of biological and clinical manipulation of the gastrointestinal tract in treating T2DM.[9,10]

Bariatric surgery, also called metabolic surgery, leads to diabetic remission in several studies by increasing insulin sensitivity in the pancreas, favorable glucose levels, and weight reduction.[11-15] Also, bariatric surgeries reduce other obesity-related comorbidities such as dyslipidemia, cardiovascular disease, and cancers.[16,17] T2DM remission rate varies in surgery-submitted obese patients (25% to 75%) versus medical management (0-6%).[11] It seems that remission and disease-free rates in patients with diabetes rely on surgery type and glycemic index.[18] Hutter and colleagues, in a study on 28 616 patients with diabetes, demonstrated that Roux-en-Y gastric bypass (RYGB) led to a higher remission rate than sleeve gastrectomy (SG) (83% vs 55%) in one-year follow-up, respectively.[19]

Despite evidence of the role of metabolic surgery in diabetic remission, associated baseline characteristics and diabetic markers affecting diabetic remission are still under debate. At least 35-50% of recovered patients experience a relapse in long-term follow-up.[20] A recent study demonstrated that after 10 years of follow-up, 53% of patients with a history of RYGB experienced a relapse of T2DM.[21] Furthermore, the relapse definition must still be fully elucidated.[22] However, poorer diabetes control before surgery, longer disease duration, and insulin injection before surgery can compromise long-term remission.[20] The role of weight regain several years after bariatric surgery is uncertain.[23] It should also be noted that following bariatric surgery, the relapse period increases in long-term observation, especially in RYGB.[24,25]

Inconsistent results of previous studies are associated with a lack of long-term follow-up, high population study, and a variety of remitting definitions that influenced the results of bariatric surgery. In this long-term observational

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study, we aimed to evaluate changes in diabetic markers, antidiabetic agents' prescription, and diabetic remission rate following bariatric surgeries.

Materials and Methods

Study Design and Participants

This retrospective observational study was conducted on patients with diabetes aged > 18 years who underwent bariatric surgery from March 2016 to July 2017 in Imam Reza hospital, a tertiary academic hospital affiliated with Mashhad University of Medical Sciences, Mashhad, Iran. Patients were divided into three groups by well-experienced bariatric surgeon who would perform RYGB, one anastomosis gastric bypass (OAGB), and SG surgery due to the amount of required weight reduction, anesthesia complications, and comorbidities. Patients who needed consensus to participate in the study or lack of medical data were excluded.

The data collected from the patients' medical records, including age, sex, surgery type, height, weight, body mass index (BMI), waist circumference (WC), abdominal circumference (BC), lipid profile (e.g., triglyceride [TG], low-density lipid [LDL], high-density lipid [HDL]), total cholesterols (TC), fasting blood sugar (FBS), HbA1C, insulin resistance, oral medications, and insulin regimen before and 5 years after bariatric surgery.

Diabetic partial remission was defined as FBS between 100-125mg/dL and HBA1C < 6.5%. Diabetic remission was defined as HBA1C < 6.0 and FBS < 100 mg/dL without ongoing medical therapy.[26] Insulin resistance was calculated by the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR).[26]

Statistical Analysis

Categorical variables were expressed as frequencies and percentages, and continuous variables were presented as mean ± standard deviation. Normal distribution was evaluated using Kolmogorov-Smirnov. Categorical data were compared by chi-square test or Fisher's exact test, as appropriate. The quantitative data were compared using the Student's t-test or Mann-Whitney test, as appropriate. For comparing qualitative variables between more than two groups, one-way analysis variance (ANOVA) was used. A P value less than 0.05 was considered statistically significant. All data were analyzed using SPSS software version 26.

Results

This study was conducted on 34 patients (88% female) with a mean age of 52.71 ± 8.53 years. The mean abdominal circumference was 109.29 ± 10.44 cm and WC was 115 ± 13.03 cm, respectively. BMI, lipid, glycemic profile, IR, and HOMA-IR were evaluated before and 5 years after surgery (Figure 1). Serum total cholesterol and LDL levels had not changed significantly during the follow-up. Overall, 22 (64%) patients had RYGB, 9 (27%) had OAGB, and 3 (9%) had SG. Additionally, no significant differences were observed in metabolic variables between the three types of surgeries. However, lower LDL reduction and increasing cholesterol serum levels were found in the RYGB group (Table 1).

Of our 34 patients, 24 patients (71%) (14 RYGB; 7 OAGB; and 3 SG) had experienced remission (50% complete remission, 21% partial remission) during 5 years of follow-up. We found no predictive factors associated with diabetic remission (Table 2). Also, we found that BMI changes in the remitted group were slightly higher versus the non-remitted group, but it was insignificant (-16.07 ± 6.22 vs -13.31 ± 6.25, P = 0.289). IR changes in the non-remitted group were slightly higher versus the remitted group, but it was also not significant (14.16 ± 9 vs 12.85 ± 14.5, P = 0.749).

In this study, despite the higher female population, no significant sex-related differences were observed in diabetic markers (P > 0.05). Insulin injection and consuming antihyperglycemic drugs as confounding variables that affected the metabolic panel were evaluated before and in follow-up time (Figure 2).

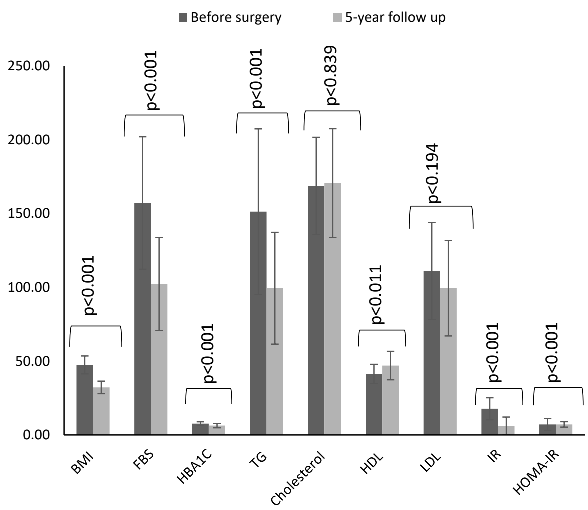

Figure 1. Comparison of metabolic markers before and 5 years after the operation. BMI: Body mass index, FBS: fasting plasma glucose, HbA1c: hemoglobin A1c, TG: triglyceride, HDL: High density lipoprotein, LDL: low density lipoprotein, IR: insulin resistance, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance

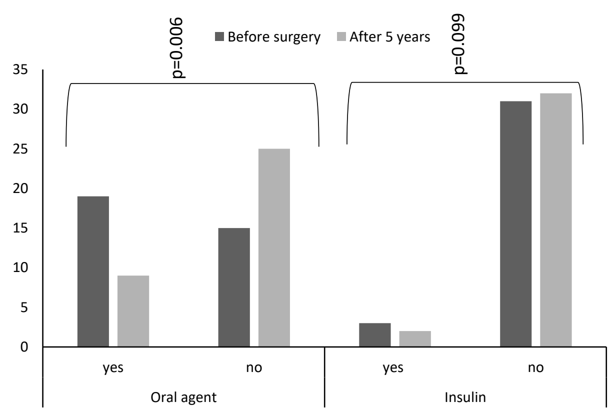

Figure 2. Comparison of oral agent and insulin injection before and 5 years after surgery

Table 1. Comparison of metabolic panel changes in three surgery types

Variables	Sleeve	RYGB	OAGB
BMI (kg/m²)	-18.0 ± 4.4	-13.8 ± 5.9	-18.0 ± 6.90
FBS (mg/dL)	-58.3 ± 34.4	-56.0 ± 61.2	-51.5 ± 44.5
HbA1c (%)	-2.2 ± 1.1	-1.4 ± 1.9	-0.94 ± 1.9
TG (mg/dL)	-112.3 ± 50.8	-44 ± 69.4	-51 ± 46.8
Cholesterol (mg/dL)	12 ± 6.2	-11.5 ± 59.9	16 ± 37.2
HDL (mg/dL)	13 ± 6.0	5.8 ± 13.7	3.1 ± 10.3
LDL (mg/dL)	-45.7 ± 12.7	-4.1 ± 59.5	-19.1 ± 32.9
IR (µIU/dL)	-7.5 ± 2.2	-11.8 ± 10.9	-11.9 ± 7.5
HOMA-IR	5.2 ± 1.5	8.9 ± 7.7	5.9 ± 1.9

BMI: Body mass index, FBS: Fasting blood sugar, Hb A1c: Hemoglobin glycosylated A1C, TG: Triglyceride, HDL: High-density lipoprotein, LDL: Low-density Lipoprotein, IR: Insulin resistance, RYGB: Roux-en-Y gastric bypass, OAGB: One anastomosis gastric bypass.

Table 2. Different factor discrepancy between the two remission groups

Variables	Remission (n = 24)	Non-remission (n = 10)	*P* value
Age	53.5 ± 8.8	60 ± 7.5	0.434
Gender (female)	22 (64.7)	8 (80.0)	0.334
BMI	48.3 ± 6.0	45.4 ± 5.9	0.208
Weight reduction	-45.3 ± 25.4	-38.2 ± 17.7	0.549
Surgery			0.288
Sleeve	3	0	
OAGB	7	2	
R-Y GB	14	8	
FBS	155.1 ± 43.8	161.4 ± 46.5	0.642
HBA1C	7.6 ± 1.3	7.6 ± 1.1	0.669
IR	6.6 ± 6.3	5.3 ± 4.6	0.254
HOMA-IR	7.7 ± 6.9	7.9 ± 5.5	0.780
TG	153.9 ± 6.7	145 ± 38.1	0.838
Chol	171.2 ± 34.2	168 ± 34.7	0.445
HDL	41 ± 6.9	42 ± 5.9	0.454
LDL	112.9 ± 34	106.9 ± 31.4	0.589

RYGB: *Roux-en-Y Gastric Bypass; OABG:* one anastomosis gastric bypass

Among our patients included in the study, in 15 patients, T2DM was diagnosed for the first time preoperatively, and they were candidates for bariatric surgery due to high BMI. 19 (60%) patients were taking antihyperglycemic agents before surgery (five patients used 500 mg metformin, eight patients used 1000 mg, and six patients used 1500 mg metformin), while just for nine (26%) patients, this situation remained after the operation ($P = 0.006$). For one patient without a history of taking oral agents despite poor control of diabetes, 1000 mg of metformin was prescribed. Eight patients had continued the previous oral agents regimen, but this time with near-optimal blood glucose control. Insulin was administered prior to surgery for three patients. Two patients used ten units of glargine, and one patient used 60 units of glargine with ten units of glulisine). Insulin was simultaneously prescribed with 500-1000 mg of metformin for patients. Among three patients, only one still used insulin post-operatively, and the insulin was changed to oral agents for two other ones. During follow-up, one patient who was taking metformin and glibenclamide for about 4 years after surgery, insulin was administered due to a high HBA1C level ($P = 0.999$).

Discussion

With the trend of utilizing metabolic surgery to alleviate metabolic markers in patients with diabetes, the role of bariatric surgery is still under debate in long-term follow-up. This was a retrospective observational study that consisted of early and late diagnosis of diabetes in patients who were candidates to undergo metabolic surgery. Our findings present that metabolic surgery plays a key role in robust alteration in three category measurements: weight loss, lipid profile, and glycemic indices. Our presentation confirmed the previous studies on weight loss and glycemic index in long-term bariatric surgery follow-ups.[27,28]

Our interesting findings were an insignificant decrease in LDL and an insignificant increase in total cholesterol. Also, in the RYGB group, LDL level reduction is lower than in other groups. The effect of bariatric surgery on reduction of cholesterol level in morbid obesity is discussable. A study by Adam and colleagues showed that LDL levels decreased by about 26% because of RYGB surgery after 6 years.[29] Another meta-analysis study on 1551 patients demonstrated a significant reduction of serum LDL levels following bariatric surgery, especially after RYGB.[30] However, Hu et al, in a meta-analysis on 7443 subjects who underwent RYGB and SG, revealed that, in more than 3 years of follow-up, comorbidities such as dyslipidemia and hypertension had not been improved significantly.[31] Also, Coleman and co-workers, in a study of 8265 patients, found lower dyslipidemia relapse in 4 years of follow-up in RYGB versus the SG group (21% vs. 24%).[32] Dyslipidemia relapse was not the scope of our study. A person would be considered as having dyslipidemia relapse if he/she has LDL level ≥ 160 mg/dL, HDL level < 40 mg/dL for men or less than 50 mg/dL for women, TC level ≥ 240 mg/dL, or triglyceride levels ≥ 200 mg/dL.[31,32] Our findings demonstrated a relapse of dyslipidemia in about 23% of our patients, 20% in the RYGB group, and 3% in the OAGB group, considering that most of our patients had undergone RYGB surgery. Noticeably, a high level of serum TC was also found in most patients who experienced dyslipidemia relapse. Since we did not follow the patients gradually, other causes, such as diet regimen adherence, may be associated with dyslipidemia progression in our patients, while taking saturated fatty acids increases LDL levels following bariatric surgery.[33,34] Albeit, after bariatric surgery, the patients' meal frequency increases.[35] Furthermore, patients' preference for low-calorie diets and sweets may fall after 18 months.[36] So, nutrition counseling is essential for maintaining the normometabolic situation following bariatric surgery.[37]

Although bariatric surgery increases diabetic remission, the advantages and disadvantages of the type of surgery, such as mortality and diabetic reversibility, remain under discussion.[38,39] In this study, we found 70% diabetic remission in our patients during 5 years of follow-up, but the type of surgery does not affect remission in our survey. Following all patients in SG and the remaining patients in another surgery group, this result is related to our patient population. A recent meta-analysis showed that SG, OAGB, and RYGB impact diabetic remission and OAGB has a higher effect on diabetic remission.[40] However, the diabetic remission mechanism is attributed to several factors, such as gastrointestinal hormones, patient adherence and compliance with treatment, and patient lifestyle.[41] Gloy et al found that bariatric surgery had a major impact on diabetic improvement, HDL level, obesity, metabolic syndrome, and quality of life compared with drug medications.[42] Among metabolic surgeries, RYGB was superior to other types of surgery.[43-45] However, Balamurugan and colleagues, in their systematic review of 82833 patients who underwent metabolic surgery, showed that SG is more effective in diabetic remission and weight loss compared with OAGB and RYGB. Despite this, the rate of SG procedures was lower than other surgeries. The heterogenicity of studies interprets the data so difficult.[46] In a study by Gentileschi et al on 78 patients with RYGB and OAGB, OAGB was found to be superior by facilitating more diabetic remission compared with RYGB in a 6-month follow-up.[47] We did not find any factors related to diabetic remission. Previous studies demonstrated that age, insulin injection, preoperative HbA1C, C-peptide level, baseline BMI, and diabetic duration were predictive factors of diabetic remission after bariatric surgery.[48-50] In a study by Stenberg et al, the authors demonstrated that diabetic remission was lower in patients who had a higher duration of diabetes, HbA1c, age, and dyslipidemia during 10 years of follow-up of RYGB surgery.[51] We collected the data from the first laboratory tests of patients. Some participants had no concerns about diabetes and did not have any history of diabetes before our first diagnostic session. So, we could not estimate the duration of diabetes and its association with the remission rate. Additionally, in our diabetic patients, the non-remitted group had higher pre-operation BMI, but it was insignificant ($P=0.208$). Although weight loss is a prior factor in alleviating diabetic markers, BMI reduction has not been considered a predictive factor for diabetic remission.[51] We found weight reduction in 5-year follow-up has not affected diabetic remission.

Adipose tissue reduction in bariatric surgery attenuates IR.[52] IR is the most important factor in glucose tolerance in patients with diabetes. Early diagnosis of T2DM with higher Beta cell remnant function and lower hepatic IR is associated with diabetic remission in a 5-year follow-up.[53] Also, bariatric surgery affects polypeptide tyrosine-tyrosine, which is associated with pancreas function, adiponectin, glucagon-like peptide 1, and C-reactive protein, which may contribute to improvements in IR.[54] Our study confirmed previous reports in the literature, which demonstrated a significant reduction in HOMA-IR following different types of metabolic surgeries.[55-58] However, it is not a predictive factor of diabetic remission in our study. Ekberg et al also demonstrated that despite evidence of HOMA-IR level reduction, it is not a predictive factor of keeping HbA1C in the normal range.[59]

Moreover, in this study, we observed a significant reduction of required oral antidiabetic agents during follow-up, which confirmed diabetic remission. This also clears the role of gastrointestinal manipulation on hormonal changes and further medications. We also observed that maintaining a metformin prescription in follow-up visits did not prevent diabetic relapse. Souteiro and colleagues also demonstrated that keeping metformin in a patient with HBA1C $<6\%$ does not show T2DM relapse.[60] These findings show that bariatric surgery requires a multidisciplinary team even after reaching a significant weight reduction.

Long-term follow-ups and three types of bariatric surgery were the strengths of this study, while the best surgery method for patients with diabetes is still the subject of debate.

One of the limitations of this study was being retrospective, and it contained bypass as the major type of surgery. The other main limitation of our study was poor patients' adherence to follow-up visits, mostly due to the COVID-19 pandemic, leading to a low study population.

Although most patients in our study were women, like the systematic review by Wang et al, sex did not affect diabetic remission during follow-ups.[18] Our study attracted attention to investigating oral drug prescriptions while selecting patients for surgeries. Despite good control of diabetes after the operation, we recommend future randomized controlled studies to evaluate medical treatment in long-term follow-ups, which involve all kinds of bariatric surgeries.

Conclusion

Our study showed favorable results of bariatric surgery on patients with diabetes in long-term follow-up. Patients who used oral antidiabetic drugs before surgery had better blood sugar control compared with patients taking insulin. Although the present study found no metabolic changes based on the three types of surgeries, it should be considered that taking oral medications after bariatric surgery were reduced. Further studies inquiring into which bariatric surgery is efficient for diabetic remission through conducting long-term follow-ups are required.

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Authors' Contribution

Conceptualization: Solmaz Hasani, Majid Khadem Rezayian, Ali Jangjoo.
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Formal analysis: Majid Khadem Rezayian.
Investigation: Zahra Behrooznia, Farid Qoorchi Moheb Seraj.

Methodology: Solmaz Hasani, Ali jangjoo, Tooraj Zandbaf.
Project administration: Solmaz Hasani.
Resources: Ali Jangjoo.
Software: Majid Khadem-Rezayian.
Supervision: Solmaz Hasani, Ali Jangjoo.
Validation: Solmaz Hasani.
Writing–original draft: Zahra Behrooznia, Farid Qoorchi Moheb Seraj.
Writing–review & editing: Solmaz Hasani, Ali jangjoo, Tooraj Zandbaf.

Competing Interests

The authors declare no conflict of interest related to this work.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical Approval

The Ethics Committee of Mashhad University of Medical Sciences approved this study (IR.MUMS.MEDICAL.REC.1400.426). All participants of the study signed the informed consent.

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References

1. Gregg EW, Cheng YJ, Narayan KM, Thompson TJ, Williamson DF. The relative contributions of different levels of overweight and obesity to the increased prevalence of diabetes in the United States: 1976-2004. *Prev Med* 2007;45(5):348-52. doi: 10.1016/j.ypmed.2007.07.020
2. Kramer H, Cao G, Dugas L, Luke A, Cooper R, Durazo-Arvizu R. Increasing BMI and waist circumference and prevalence of obesity among adults with type 2 diabetes: the National Health and Nutrition Examination Surveys. *J Diabetes Complications* 2010;24(6):368-74. doi: 10.1016/j.jdiacomp.2009.10.001
3. Nathan DM, Buse JB, Davidson MB, Ferrannini E, Holman RR, Sherwin R, et al. Medical management of hyperglycemia in type 2 diabetes: a consensus algorithm for the initiation and adjustment of therapy: a consensus statement of the American Diabetes Association and the European Association for the Study of Diabetes. *Diabetes Care* 2009;32(1):193-203. doi: 10.2337/dc08-9025
4. Shaw JE, Sicree RA, Zimmet PZ. Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Res Clin Pract* 2010;87(1):4-14. doi: 10.1016/j.diabres.2009.10.007
5. Liebl A, Mata M, Eschwège E. Evaluation of risk factors for development of complications in type II diabetes in Europe. *Diabetologia* 2002;45(7):S23-8. doi: 10.1007/s00125-002-0863-0
6. Pinkney JH, Sjöström CD, Gale EA. Should surgeons treat diabetes in severely obese people? *Lancet* 2001;357(9265):1357-9. doi: 10.1016/s0140-6736(00)04524-4
7. Cătoi AF, Pârvu A, Mureşan A, Busetto L. Metabolic mechanisms in obesity and type 2 diabetes: insights from bariatric/metabolic surgery. *Obes Facts* 2015;8(6):350-63. doi: 10.1159/000441259
8. Guerreiro V, Neves JS, Salazar D, Ferreira MJ, Oliveira SC, Souteiro P, et al. Long-term weight loss and metabolic syndrome remission after bariatric surgery: the effect of sex, age, metabolic parameters and surgical technique - a 4-year follow-up study. *Obes Facts* 2019;12(6):639-52. doi: 10.1159/000503753
9. Cefalu WT, Rubino F, Cummings DE. Metabolic surgery for type 2 diabetes: changing the landscape of diabetes care. *Diabetes Care* 2016;39(6):857-60. doi: 10.2337/dc16-0686
10. Sjöström L, Lindroos AK, Peltonen M, Torgerson J, Bouchard C, Carlsson B, et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *N Engl J Med* 2004;351(26):2683-93. doi: 10.1056/NEJMoa035622
11. Chumakova-Orin M, Vanetta C, Moris DP, Guerron AD. Diabetes remission after bariatric surgery. *World J Diabetes* 2021;12(7):1093-101. doi: 10.4239/wjd.v12.i7.1093
12. Dixon JB, le Roux CW, Rubino F, Zimmet P. Bariatric surgery for type 2 diabetes. *Lancet* 2012;379(9833):2300-11. doi: 10.1016/s0140-6736(12)60401-2
13. Jørgensen NB, Jacobsen SH, Dirksen C, Bojsen-Møller KN, Naver L, Hvolris L, et al. Acute and long-term effects of Roux-en-Y gastric bypass on glucose metabolism in subjects with type 2 diabetes and normal glucose tolerance. *Am J Physiol Endocrinol Metab* 2012;303(1):E122-31. doi: 10.1152/ajpendo.00073.2012
14. Martinussen C, Bojsen-Møller KN, Dirksen C, Jacobsen SH, Jørgensen NB, Kristiansen VB, et al. Immediate enhancement of first-phase insulin secretion and unchanged glucose effectiveness in patients with type 2 diabetes after Roux-en-Y gastric bypass. *Am J Physiol Endocrinol Metab* 2015;308(6):E535-44. doi: 10.1152/ajpendo.00506.2014
15. Steven S, Hollingsworth KG, Small PK, Woodcock SA, Pucci A, Aribasala B, et al. Calorie restriction and not glucagon-like peptide-1 explains the acute improvement in glucose control after gastric bypass in type 2 diabetes. *Diabet Med* 2016;33(12):1723-31. doi: 10.1111/dme.13257
16. Adams TD, Gress RE, Smith SC, Halverson RC, Simper SC, Rosamond WD, et al. Long-term mortality after gastric bypass surgery. *N Engl J Med* 2007;357(8):753-61. doi: 10.1056/NEJMoa066603
17. Buchwald H, Avidor Y, Braunwald E, Jensen MD, Pories W, Fahrbach K, et al. Bariatric surgery: a systematic review and meta-analysis. *JAMA* 2004;292(14):1724-37. doi: 10.1001/jama.292.14.1724
18. Wang GF, Yan YX, Xu N, Yin D, Hui Y, Zhang JP, et al. Predictive factors of type 2 diabetes mellitus remission following bariatric surgery: a meta-analysis. *Obes Surg* 2015;25(2):199-208. doi: 10.1007/s11695-014-1391-y
19. Hutter MM, Schirmer BD, Jones DB, Ko CY, Cohen ME, Merkow RP, et al. First report from the American College of Surgeons Bariatric Surgery Center Network: laparoscopic sleeve gastrectomy has morbidity and effectiveness positioned between the band and the bypass. *Ann Surg* 2011;254(3):410-20. doi: 10.1097/SLA.0b013e31822c9dac
20. Arterburn DE, Bogart A, Sherwood NE, Sidney S, Coleman KJ, Haneuse S, et al. A multisite study of long-term remission and relapse of type 2 diabetes mellitus following gastric bypass. *Obes Surg* 2013;23(1):93-102. doi: 10.1007/s11695-012-0802-1
21. Mingrone G, Panunzi S, De Gaetano A, Guidone C, Iaconelli A, Capristo E, et al. Metabolic surgery versus conventional medical therapy in patients with type 2 diabetes: 10-year follow-up of an open-label, single-centre, randomised controlled trial. *Lancet* 2021;397(10271):293-304. doi: 10.1016/s0140-6736(20)32649-0
22. Elhag W, Lock M, El Ansari W. When definitions differ, are comparisons meaningful? Definitions of weight regain after bariatric surgery and their associations with patient characteristics and clinical outcomes - a need for a revisit? *Obes Surg* 2023;33(5):1390-400. doi: 10.1007/s11695-023-06528-z
23. Aminian A, Vidal J, Salminen P, Still CD, Nor Hanipah Z, Sharma G, et al. Late relapse of diabetes after bariatric surgery: not rare, but not a failure. *Diabetes Care* 2020;43(3):534-40. doi: 10.2337/dc19-1057
24. Adams TD, Davidson LE, Litwin SE, Kim J, Kolotkin RL, Nanjee MN, et al. Weight and metabolic outcomes 12 years after gastric bypass. *N Engl J Med* 2017;377(12):1143-55. doi:

10.1056/NEJMoa1700459

25. Courcoulas AP, Gallagher JW, Neiberg RH, Eagleton EB, DeLany JP, Lang W, et al. Bariatric surgery vs lifestyle intervention for diabetes treatment: 5-year outcomes from a randomized trial. *J Clin Endocrinol Metab* 2020;105(3):866-76. doi: 10.1210/clinem/dgaa006
26. de Azevedo Salgado AL, de Carvalho L, Oliveira AC, dos Santos VN, Vieira JG, Parise ER. Insulin resistance index (HOMA-IR) in the differentiation of patients with non-alcoholic fatty liver disease and healthy individuals. *Arq Gastroenterol* 2010;47(2):165-9. doi: 10.1590/s0004-28032010000200009
27. Hampl SE, Hassink SG, Skinner AC, Armstrong SC, Barlow SE, Bolling CF, et al. Clinical practice guideline for the evaluation and treatment of children and adolescents with obesity. *Pediatrics* 2023;151(2):e2022060640. doi: 10.1542/peds.2022-060640
28. Wu Z, Gao Z, Qiao Y, Chen F, Guan B, Wu L, et al. Long-term results of bariatric surgery in adolescents with at least 5 years of follow-up: a systematic review and meta-analysis. *Obes Surg* 2023;33(6):1730-45. doi: 10.1007/s11695-023-06593-4
29. Adams TD, Davidson LE, Litwin SE, Kolotkin RL, LaMonte MJ, Pendleton RC, et al. Health benefits of gastric bypass surgery after 6 years. *JAMA* 2012;308(11):1122-31. doi: 10.1001/2012.jama.11164
30. Jamialahmadi T, Reiner Ž, Alidadi M, Kroh M, Almahmeed W, Ruscica M, et al. The effect of bariatric surgery on circulating levels of lipoprotein(a): a meta-analysis. *Biomed Res Int* 2022;2022:8435133. doi: 10.1155/2022/8435133
31. Hu Z, Sun J, Li R, Wang Z, Ding H, Zhu T, et al. A comprehensive comparison of LRYGB and LSG in obese patients including the effects on QoL, comorbidities, weight loss, and complications: a systematic review and meta-analysis. *Obes Surg* 2020;30(3):819-27. doi: 10.1007/s11695-019-04306-4
32. Coleman KJ, Basu A, Barton LJ, Fischer H, Arterburn DE, Barthold D, et al. Remission and relapse of dyslipidemia after vertical sleeve gastrectomy vs Roux-en-Y gastric bypass in a racially and ethnically diverse population. *JAMA Netw Open* 2022;5(9):e2233843. doi: 10.1001/jamanetworkopen.2022.33843
33. Arnett DK, Blumenthal RS, Albert MA, Buroker AB, Goldberger ZD, Hahn EJ, et al. 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation* 2019;140(11):e596-e646. doi: 10.1161/cir.0000000000000678
34. Julibert A, Bibiloni MDM, Bouzas C, Martínez-González M, Salas-Salvadó J, Corella D, et al. Total and subtypes of dietary fat intake and its association with components of the metabolic syndrome in a mediterranean population at high cardiovascular risk. *Nutrients* 2019;11(7):1493. doi: 10.3390/nu11071493
35. Alabduljabbar K, Al-Najim W, le Roux CW. Food preferences after bariatric surgery: a review update. *Intern Emerg Med* 2023;18(2):351-8. doi: 10.1007/s11739-022-03157-9
36. Søndergaard Nielsen M, Rasmussen S, Just Christensen B, Ritz C, le Roux CW, Berg Schmidt J, et al. Bariatric surgery does not affect food preferences, but individual changes in food preferences may predict weight loss. *Obesity (Silver Spring)* 2018;26(12):1879-87. doi: 10.1002/oby.22272
37. Bettini S, Belligoli A, Fabris R, Busetto L. Diet approach before and after bariatric surgery. *Rev Endocr Metab Disord* 2020;21(3):297-306. doi: 10.1007/s11154-020-09571-8
38. Alqunai MS, Alrashid FF. Bariatric surgery for the management of type 2 diabetes mellitus-current trends and challenges: a review article. *Am J Transl Res* 2022;14(2):1160-71.
39. Davies MJ, Aroda VR, Collins BS, Gabbay RA, Green J, Maruthur NM, et al. Management of hyperglycaemia in type 2 diabetes, 2022. A consensus report by the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD). *Diabetologia* 2022;65(12):1925-66. doi: 10.1007/s00125-022-05787-2
40. Balasubaramaniam V, Pouwels S. Remission of type 2 diabetes mellitus (T2DM) after sleeve gastrectomy (SG), one-anastomosis gastric bypass (OAGB), and Roux-en-Y gastric bypass (RYGB): a systematic review. *Medicina (Kaunas)* 2023;59(5):985. doi: 10.3390/medicina59050985
41. Pereira SS, Guimarães M, Monteiro MP. Towards precision medicine in bariatric surgery prescription. *Rev Endocr Metab Disord* 2023;24(5):961-77. doi: 10.1007/s11154-023-09801-9
42. Gloy VL, Briel M, Bhatt DL, Kashyap SR, Schauer PR, Mingrone G, et al. Bariatric surgery versus non-surgical treatment for obesity: a systematic review and meta-analysis of randomised controlled trials. *BMJ* 2013;347:f5934. doi: 10.1136/bmj.f5934
43. Akpinar EO, Liem RSL, Nienhuijs SW, Greve JWM, Marang-van de Mheen PJ. Weight recurrence after Sleeve Gastrectomy versus Roux-en-Y gastric bypass: a propensity score matched nationwide analysis. *Surg Endosc* 2023;37(6):4351-9. doi: 10.1007/s00464-022-09785-8
44. Currie AC, Askari A, Fangueiro A, Mahawar K. Network meta-analysis of metabolic surgery procedures for the treatment of obesity and diabetes. *Obes Surg* 2021;31(10):4528-41. doi: 10.1007/s11695-021-05643-z
45. McTigue KM, Wellman R, Nauman E, Anau J, Coley RY, Odor A, et al. Comparing the 5-year diabetes outcomes of sleeve gastrectomy and gastric bypass: the National Patient-Centered Clinical Research Network (PCORNet) Bariatric Study. *JAMA Surg* 2020;155(5):e200087. doi: 10.1001/jamasurg.2020.0087
46. Balamurugan G, Leo SJ, Sivagnanam ST, Balaji Prasad S, Ravindra C, Rengan V, et al. Comparison of efficacy and safety between Roux-en-Y gastric bypass (RYGB) vs one anastomosis gastric bypass (OAGB) vs single anastomosis duodeno-ileal bypass with sleeve gastrectomy (SADI-S): a systematic review of bariatric and metabolic surgery. *Obes Surg* 2023;33(7):2194-209. doi: 10.1007/s11695-023-06602-6
47. Gentileschi P, Siragusa L, Alicata F, Campanelli M, Bellantone C, Musca T, et al. Nutritional status after Roux-en-Y (RYGB) and one anastomosis gastric bypass (OAGB) at 6-month follow-up: a comparative study. *Nutrients* 2022;14(14):2823. doi: 10.3390/nu14142823
48. Aminian A, Brethauer SA, Andalib A, Nowacki AS, Jimenez A, Corcelles R, et al. Individualized metabolic surgery score: procedure selection based on diabetes severity. *Ann Surg* 2017;266(4):650-7. doi: 10.1097/sla.0000000000002407
49. Lee WJ, Hur KY, Lakadawala M, Kasama K, Wong SK, Chen SC, et al. Predicting success of metabolic surgery: age, body mass index, C-peptide, and duration score. *Surg Obes Relat Dis* 2013;9(3):379-84. doi: 10.1016/j.soard.2012.07.015
50. Still CD, Wood GC, Benotti P, Petrick AT, Gabrielsen J, Strodel WE, et al. Preoperative prediction of type 2 diabetes remission after Roux-en-Y gastric bypass surgery: a retrospective cohort study. *Lancet Diabetes Endocrinol* 2014;2(1):38-45. doi: 10.1016/s2213-8587(13)70070-6
51. Stenberg E, Olbers T, Cao Y, Sundbom M, Jans A, Ottosson J, et al. Factors determining chance of type 2 diabetes remission after Roux-en-Y gastric bypass surgery: a nationwide cohort study in 8057 Swedish patients. *BMJ Open Diabetes Res Care* 2021;9(1):e002033. doi: 10.1136/bmjdrc-2020-002033
52. Mocciaro G, Gastaldelli A. Obesity-related insulin resistance: the central role of adipose tissue dysfunction. *Handb Exp Pharmacol* 2022;274:145-64. doi: 10.1007/164_2021_573
53. Roncero-Ramos I, Gutierrez-Mariscal FM, Gomez-Delgado F, Villasanta-Gonzalez A, Torres-Peña JD, de la Cruz-Ares S, et

al. Beta cell functionality and hepatic insulin resistance are major contributors to type 2 diabetes remission and starting pharmacological therapy: from CORDIOPREV randomized controlled trial. *Transl Res* 2021;238:12-24. doi: 10.1016/j.trsl.2021.07.001

54. Brzozowska MM, Isaacs M, Bliuc D, Baldock PA, Eisman JA, White CP, et al. Effects of bariatric surgery and dietary intervention on insulin resistance and appetite hormones over a 3 year period. *Sci Rep* 2023;13(1):6032. doi: 10.1038/s41598-023-33317-6
55. Lee WJ, Chong K, Ser KH, Lee YC, Chen SC, Chen JC, et al. Gastric bypass vs sleeve gastrectomy for type 2 diabetes mellitus: a randomized controlled trial. *Arch Surg* 2011;146(2):143-8. doi: 10.1001/archsurg.2010.326
56. Liu DF, Ma ZY, Zhang CS, Lin Q, Li MW, Su KZ, et al. The effects of bariatric surgery on dyslipidemia and insulin resistance in overweight patients with or without type 2 diabetes: a systematic review and network meta-analysis. *Surg Obes Relat Dis* 2021;17(9):1655-72. doi: 10.1016/j.soard.2021.04.005
57. Mullally JA, Febres GJ, Bessler M, Korner J. Sleeve gastrectomy and Roux-en-Y gastric bypass achieve similar early improvements in beta-cell function in obese patients with type 2 diabetes. *Sci Rep* 2019;9(1):1880. doi: 10.1038/s41598-018-38283-y
58. Ozmen MM, Guldogan CE, Gundogdu E. Changes in HOMA-IR index levels after bariatric surgery: comparison of single anastomosis duodenal switch-proximal approach (SADS-p) and one anastomosis gastric bypass-mini gastric bypass (OAGB-MGB). *Int J Surg* 2020;78:36-41. doi: 10.1016/j.ijsu.2020.04.008
59. Ekberg NR, Falhammar H, Näslund E, Brismar K. Predictors of normalized HbA1c after gastric bypass surgery in subjects with abnormal glucose levels, a 2-year follow-up study. *Sci Rep* 2020;10(1):15127. doi: 10.1038/s41598-020-72141-0
60. Souteiro P, Belo S, Magalhães D, Pedro J, Neves JS, Oliveira SC, et al. Long-term diabetes outcomes after bariatric surgery-managing medication withdrawl. *Int J Obes (Lond)* 2019;43(11):2217-24. doi: 10.1038/s41366-019-0320-5