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Original article

Metabolic effects of bariatric surgery on patients with type 2 diabetes: a population-based study

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Abstract

Background: Bariatric surgery among patients with obesity and type 2 diabetes (T2D) can induce complete remission. However, it remains unclear whether sleeve gastrectomy (SG) or Roux-en-Y gastric bypass (RYGB) has better T2D remission within a population-based daily practice.

Objectives: To compare patients undergoing RYGB and SG on the extent of T2D remission at the 1-year follow-up.

Setting: Nationwide, population-based study including all 18 hospitals in the Netherlands providing metabolic and bariatric surgery.

Methods: Patients undergoing RYGB and SG between October 2015 and October 2018 with 1 year of complete follow-up data were selected from the mandatory nationwide Dutch Audit for Treatment of Obesity (DATO). The primary outcome is T2D remission within 1 year. Secondary outcomes include ≥20% total weight loss (TWL), obesity-related co-morbidity reduction, and postoperative complications with a Clavien-Dindo (CD) grade ≥III within 30 days. We compared T2D remission between RYGB and SG groups using propensity score matching to adjust for confounding by indication.

Results: A total of 5015 patients were identified from the DATO, and 4132 (82.4%) had completed a 1-year follow-up visit. There were 3350 (66.8%) patients with a valid T2D status who were included in the analysis (RYGB = 2623; SG = 727). RYGB patients had a lower body mass index than SG patients, but were more often female, with higher gastroesophageal reflux disease and dyslipidemia rates. After adjusting for these confounders, RYGB patients had increased odds of achieving T2D remission (odds ratio [OR], 1.54; 95% confidence interval [CI], 1.14–2.1; $P < .01$). Groups were balanced after matching 695 patients in each group. After matching, RYGB patients still had better odds of T2D remission (OR, 1.91; 95% CI, 1.27–2.88; $P < .01$). Also, significantly more RYGB patients had ≥20%TWL (OR, 2.71; 95% CI, 1.96–3.75; $P < .01$) and RYGB patients had higher dyslipidemia remission rates (OR, 1.96; 95% CI, 1.39–2.76; $P < .01$). There were no significant differences in CD ≥III complications.

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Conclusion: Using population-based data from the Netherlands, this study shows that RYGB leads to better T2D remission rates at the 1-year follow-up and better metabolic outcomes for patients with obesity and T2D undergoing bariatric surgery in daily practice. (Surg Obes Relat Dis 2021;17:1349–1358.)

Keywords: Bariatric surgery; Population-based; Roux-en-Y gastric bypass; Sleeve gastrectomy; Propensity score matching; Type 2 diabetes

Bariatric surgery is well established in the Netherlands, as in other countries, and has proven to be safe and effective in weight loss and obesity-related co-morbidity reduction [1]. It is increasingly performed in patients with obesity and type 2 diabetes (T2D), as metabolic surgery can lead to complete remission [2]. Sleeve gastrectomy (SG) is currently the most frequently performed technique worldwide, as studies are showing that it results in less morbidity and similar co-morbidity reductions compared with Roux-en-Y gastric bypass (RYGB) [3]. Nevertheless, a recent study describes that surgeon factors and expertise are highly associated with the decision for a specific bariatric technique and shows a higher likelihood for patients with T2D to undergo RYGB [4].

Patient characteristics are known to be associated with the likelihood of diabetes remission. For instance, a longer duration of T2D is negatively associated with T2D remission [5]. However, profound weight loss is associated with higher chances of T2D remission [6,7]. There are systematic reviews and meta-analyses that show more favorable outcomes, in terms of T2D remission and weight loss, after RYGB compared with SG [8–10]. However, these reviews mostly contain retrospective and observational studies, which may be prone to bias if there is an underlying reason why patients get 1 treatment or the other. Recent randomized controlled trials (RCTs) like the Swiss Multicenter Bypass or Sleeve Study (SM-BOSS), the Sleeve vs Bypass (SLEEVEPASS), and Surgical Therapy And Medications Potentially Eradicate Diabetes Efficiently (STAMPEDE) trials all show similar outcomes for RYGB versus SG, with no significant difference in T2D remission after 5 years [11–13]. But even though these studies are RCTs, some of them are underpowered and include only a selected group of patients, and are therefore not generalizable to the whole population in daily practice. With the increasing prevalence of obesity-related T2D worldwide and surgeons' desire to choose the bariatric treatment with the best chances for T2D remission, the need for guidance and population-based results is increasing [14].

Population-based data are valuable, as they include all patients treated in daily clinical practice, rather than a selected group of patients. However, the estimated treatment effects from observational studies may be biased if there is an underlying reason for patients getting one treatment over the other (confounding by indication), whereas this is not a problem in trials due to randomization [15]. Propensity score matching (PSM) is a statistical pseudo-randomization technique that adjusts for confounding by indication, to ensure analyses are comparing patients with the same chance of receiving a treatment [16]. This study therefore aims to compare patients undergoing RYGB and SG on the extent of T2D remission at 1 year of follow-up using population-based data from the Netherlands, while adjusting for confounding by indication using PSM.

Methods

Study design

This is a population-based cohort within the Dutch Audit for Treatment of Obesity (DATO). The DATO is a mandatory registry containing patient data from all hospitals performing bariatric surgery in the Netherlands [17]. The Dutch Surgical Association for Bariatric and Metabolic Surgery has a minimum volume standard of 200 primary procedures annually, with a minimum of 2 dedicated bariatric surgeons. Every 2 years, a third independent party conducts an onsite validation of the data provided by the bariatric centers [17]. The scientific committee of the DATO unanimously approved using the data to perform this study. Every DATO year runs from October until October of the next year, so in practice, all operated patients can reasonably have a 1-year follow-up appointment at the outpatient clinic by the end of December in the year following their surgery. The mandatory follow-up program in the Netherlands has a duration of 5 years. The postoperative follow-up visits at the surgical outpatient clinic for the first year are planned at approximately 3, 6, 9, and 12 months. To determine the T2D status at 1 year, patients need an outpatient clinic visit between 9–15 months postoperatively. This is a nationally predefined interval for co-morbidity status and weight loss, and from now on this visit will be referred to as the 1-year follow-up.

Patient selection

All patients with T2D undergoing primary bariatric surgery in the Netherlands from October 2, 2015, until October 1, 2018, were eligible for this study if they had a surgical outpatient clinic visit within the first year and before January 1, 2020. Further inclusion criteria were having T2D present at baseline, being 18–65 years old on the day

of surgery, and having an outpatient clinic visit between 9 and 15 months postoperatively to determine the T2D status. T2D at baseline is defined as glycated hemoglobin (HbA1C) ≥53 mmol HbA1C/mol HbA, and classified by surgeons as being either without medication or with medication (e.g., oral antidiabetic agent or insulin-dependent), regardless of HbA1C. To determine the estimated treatment effect on T2D remission, we only included complete cases with a valid T2D status at the 1-year follow-up (Fig. 1).

Outcome parameters

The primary outcome is T2D remission at the 1-year follow-up after bariatric surgery. The status of T2D at the 1-year follow-up is compared with the status at the preoperative screening and classified by bariatric surgeons as either complete remission, partial remission/improvement, unchanged, or deteriorated. Complete remission is defined as an HbA1C <53 mmol HbA1C/mol HbA in absence of diabetic medication, as stated in the international guidelines [18]. Partial remission is defined as a decrease in HbA1C (to ≤69 mmol HbA1C/mol HbA) and/or a decrease in use of diabetic medication. Deterioration denotes a significant increase in HbA1C (to >69 mmol HbA1C/mol HbA) and/or an increase in use of diabetic medication. Unchanged means no remission, improvement, or deterioration as described above. For the present study, remission of T2D is defined as complete or partial remission, with no remission defined as unchanged or deterioration.

Secondary outcomes include hypertension, dyslipidemia, gastroesophageal reflux disease (GERD), musculoskeletal pain, and obstructive sleep apnea syndrome (OSAS). These obesity-related co-morbidities were also compared with their respective status at the preoperative screening and reported as having complete remission, having improvement, being unchanged, deteriorating, de novo, or not being applicable (meaning not present/unknown status at the 1-year follow-up). The definitions of all co-morbidity statuses are listed in Fig. 2. Other secondary outcomes include ≥20%

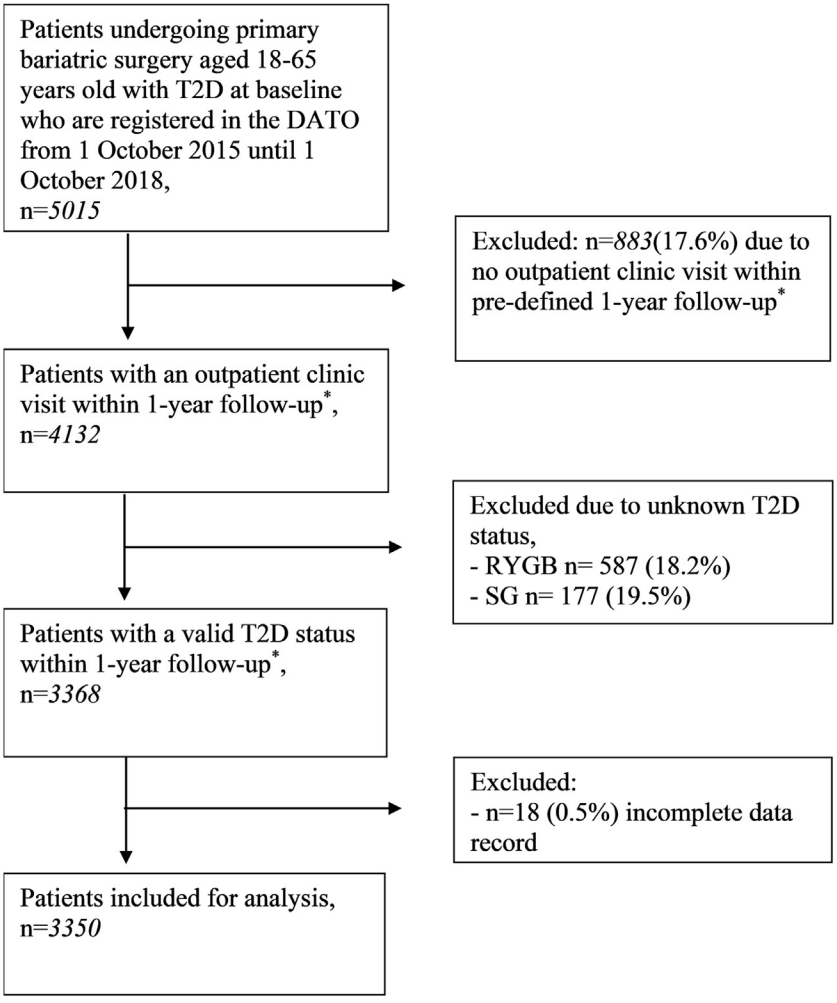

Fig. 1. Flowchart of included patients. *Patients with an outpatient clinic visit between 9 and 15 months postoperatively. T2D = type 2 diabetes; DATO = Dutch Audit for Treatment of Obesity; RYGB = Roux-en-Y gastric bypass; SG = sleeve gastrectomy.

Outcome	Type 2 Diabetes	Dyslipidemia	Hypertension	GERD	OSAS	Musculoskeletal pain
Complete remission	HbA1c (<53 mmol HbA1c/mol HbA) in absence of diabetic medication.	Normal lipid spectrum (LDL, HDL, Triglycerides) without use of cholesterol lowering drugs	Normotensive (<120/80 mmHg) without use of antihypertensive drugs	Absence of symptoms, no medication use and a normal physiological test (by 24-48 hours pH measurement or by gastro-duodenoscopy)	No symptoms after preoperative diagnosis of OSAS by means of poly(somno) graphs (PSG), in combination with apnea-hypopnea index (AHI) <5 and no (more) use of CPAP/BiPAP	No symptoms after pre-operative diagnosis of joint complaints, without the use of any analgesics
Improvement/ partial remission	Decrease in HbA1c (≤69 mmol HbA1c/mol HbA) and/or decrease in diabetic medication (i.e. when stopping insulin use or stopping at least one oral tablet or halving dose)	Reduction of cholesterol lowering drugs while maintaining or improving the lipid spectrum / or improvement in lipid spectrum with same amount of drugs	Dose reduction and/or reduction in use of antihypertensive drugs or a decrease in systolic and diastolic blood pressure using the same drugs	Reduction of symptoms or reduction of medication use / or improvement with physiological test (by 24-48 hours pH measurement or by gastro-duodenoscopy)	Decrease in symptoms after pre-operative diagnosis of OSAS with reduction in CPAP/BiPAP pressure, improvement of AHI and/ or improvement of PSG	Decrease in symptoms of joint complaints and/or reduction/ decrease in use of analgesics
Unchanged	Absence of improvement or deterioration	Absence of improvement or deterioration	Absence of improvement or deterioration	Absence of improvement or deterioration	Absence of improvement or deterioration	Absence of improvement or deterioration
Deterioration/ recurrence	Deterioration denotes significant increase in HbA1c (>69 mmol HbA1c/mol HbA), increase in diabetic medication and/or (re)starting diabetic medication	Deterioration of the lipid spectrum and/or increase in medication and/or (re) starting cholesterol lowering drugs after period of absence	The need to (re) start and / or increase antihypertensive drugs with increasing systolic and / or diastolic blood pressure	Worsening of symptoms and/or increase in medication and/or (re) starting medication after period of absence	Worsening of symptoms and/ or (re) starting (increase) in CPAP/BiPAP pressure	Worsening of symptoms and/or increase in medication and/or (re) starting the use of analgesics
De novo	-	New diagnosis	New diagnosis	New diagnosis	New diagnosis	New diagnosis

Fig. 2. Definitions of outcomes for obesity-related co-morbidities after bariatric surgery. GERD = gastroesophageal reflux disease; OSAS = obstructive sleep apnea syndrome; HbA1c = glycated hemoglobin; LDL = low-density lipoprotein; HDL = high-density lipoprotein; CPAP = continuous positive airway pressure; BIPAP = bilevel positive airway pressure; AHI = Apnea-Hypopnea Index; PSG = polysomnography.

total weight loss (TWL) at the 1-year follow-up (TWL = [preoperative weight – follow-up weight] / preoperative weight), prolonged length of stay (>2 d), and any severe postoperative complications, defined as those having a Clavien-Dindo (CD) Classification of Surgical Complications grade ≥III within 30 days [17].

Statistical analysis

To compare baseline characteristics between the RGYB and SG groups, the χ^2 test was used for categorical variables and the Student *t* test was used for parametric continuous variables. The paired Student *t* test was used to compare continuous variables at baseline and postoperatively. A P value $< .05$ is considered as statistically significant. To compare patients undergoing RGYB and SG on T2D remission at the 1-year follow-up, multivariable logistic regression was performed, adjusting for confounders (before matching). Based on literature [2,19,20] and clinical experience, the following covariates were included in our multivariable model: sex, age, year of operation, baseline body mass index (BMI), T2D with or without medication, American Society of Anesthesiologists (ASA) classification, hypertension, dyslipidemia, and OSAS. Musculoskeletal pain and GERD are known not to be associated with T2D remission [21].

PSM was conducted to adjust for confounding by indication, so that patients with the same likelihood of undergoing a bariatric technique were compared. Patients were matched on the following baseline variables: sex, age, year of operation, preoperative BMI, T2D with or without medication at baseline, ASA classification, hypertension, dyslipidemia, GERD, musculoskeletal pain, and OSAS. The nearest neighbor method was used to match patients 1:1 with a caliper of .20. A standardized mean difference $< .1$ was considered to show balanced groups. A logistic regression analysis was performed, relating the outcome to the bariatric procedure group and adjusting for the propensity score [16]. This PSM analysis was conducted for the primary and secondary outcomes. We also conducted an additional analysis using PSM with the primary outcome of T2D remission defined as complete remission and no remission defined as partial remission, an unchanged status, or deterioration, to see whether this affected the results. Analyses were performed in R version 3.4.2 using the "MatchIt" 3.0.2 package.

Sensitivity analysis

There may be several reasons for a T2D status to be unknown/missing T2Dat the 1-year follow-up, and these patients were excluded from the primary analysis. In the Netherlands, patients prefer the nearest outside laboratory for venipuncture samples for HbA1C or have a venipuncture after a visit to the outpatient clinic. Also, using the predefined interval of between 9 and 15 months postoperatively to determine the T2D status will exclude any patient with an HbA1C assessment 1 day outside this period. Another reason is that endocrinologists refer patients with adequate glycemic control back to primary care. All these reasons make it logistically challenging for surgeons to retrieve the results from HbA1c samples to define the actual T2D status. With comparable missing percentages between groups and the aforementioned reasons, an unknown T2D status at the 1-year follow-up is likely to be missing at random. To gain insight into the extent to which an unknown T2D status could influence our results, we conducted a sensitivity analysis. For this analysis, we assumed all the unknown/missing T2D statuses (Fig. 1) to be either improved or not improved at the 1-year follow-up. The same procedure with PSM and a subsequent analysis was then conducted. Comparing patient characteristics for patients with and without missing T2D data at 1 year shows that on average, those with missing data are healthier patients (Supplementary Table A), which could suggest that those patients are more likely to have improvements.

Results

Study population

Between October 1, 2015, and October 1, 2018, a total of 5015 patients with obesity and T2D who underwent bariatric surgery were eligible for this study, and 4132 (82.4%) completed the predefined 1-year follow-up. Of these, a total of 3350 (81.1%) patients with complete data and known T2D status were included in the analysis. Table 1 shows that patients who received RYGB were significantly more likely to be female compared with SG patients (69.1% versus 59%, respectively), had GERD more often (15.1% versus 10.7%, respectively), and had dyslipidemia more often (36.5% versus 30.1%, respectively). However, on average RYGB patients had a lower BMI (42 [standard deviation, 5.0] versus 45 [standard deviation, 7.0], respectively) and were less likely to be ASA III (52.8% versus 66%, respectively) than SG patients. A total of 695 patients could be matched in each group, resulting in balanced groups with no significant differences in baseline characteristics, as shown in Table 1.

Primary and secondary outcomes

For the primary outcome, Table 2 shows that patients undergoing RYGB had higher odds of achieving complete or partial T2D remission within 1 year, after adjusting for confounders (odds ratio [OR], 1.54; 95% confidence interval [CI], 1.14–2.1; $P < .01$). The same significant effect remained after PSM was applied to adjust for confounding by indication (OR, 1.91; 95% CI, 1.27–2.88; $P < .01$; Table 3), meaning that the results were still favorable for RYGB when comparing patients who were equally likely to receive either procedure.

The secondary outcomes listed in Table 3 show that patients undergoing RYGB also had higher odds of achieving ≥20% TWL (OR, 2.71; 95% CI, 1.96–3.75; $P < .01$) and dyslipidemia remission at the 1-year follow-up (OR, 1.96; 95% CI, 1.39–2.76; $P < .01$). After matching, the BMI was significantly decreased at 1 year compared with baseline for both the RYGB group (Δ BMI 1 yr = −13.4; 95% CI, −13.1 to −13.7; $P < .01$) and the SG group (Δ BMI 1 year = −11.8; 95% CI, −11.5 to −12.2; $P < .01$). On average, the decrease in BMI was significantly higher after 1 year in the RYGB group compared with the SG group (−13.4 ± 4.5 versus −11.8 ± 4.2, respectively; $P < .001$). There were no significant differences in rates of CD ≥III complications ($P = .083$) and no deceased patients in either group.

The analysis including only complete remission showed similar results, with RYGB still having a favorable effect after PSM (OR, 1.35; 95% CI, 1.09–1.69; $P < .01$).

Sensitivity analysis

The sensitivity analysis included patients with a missing/unknown T2D status (n = 764) despite having had a 1-year follow-up outpatient clinic visit, resulting in a total of 4132 patients (Fig. 1). We assumed all the unknown/missing T2D statuses for the RYGB (n = 587; 18.2%) and SG (n = 177; 19.5%) groups as being either improved or not improved at the 1-year follow-up, to gauge the impact of these missing data on the results (Supplementary Table A). When defining all unknown/missing T2D statuses at the 1-year follow-up as improved, RYGB remained associated with better T2D remission compared with SG (OR, 1.48; 95% CI, 1.01–2.16; $P < .05$). When defining all unknown/missing T2D statuses at the 1-year follow-up as not improved, RYGB still was associated with better T2D remission compared with SG (OR, 1.26; 95% CI, 1.02–1.57; $P < .05$).

Discussion

This nationwide study shows that patients undergoing RYGB are more likely to have T2D remission at the 1-year follow-up compared with SG patients in a population-based matched cohort. To our knowledge, this study is the largest matched population-based study concerning patients with obesity and T2D, presenting strong evidence using PSM while still including unselected patients treated in daily practice. RYGB was also associated with

Table 1
Patient characteristics for Roux-en-Y gastric bypass and sleeve gastrectomy before and after matching

Characteristic	Before matching				After matching			
	RYGB, n = 2623	SG, n = 727	*P* value	SMD	RGYB, n = 695	SG, n = 695	*P* value	SMD
Sex, n (%)								
Male	810 (30.9)	298 (41.0)	<.001	.212	284 (40.9)	279 (40.1)	.827	<.1
Female	1813 (69.1)	429 (59.0)			411 (59.1)	416 (59.9)		
Age, mean (SD)	51 (9)	51 (9)	.141	.060	51 (9)	51 (9)	.648	<.1
BMI, mean (SD), kg/m^2	42 (5)	45 (7)	<.001	.525	44 (6)	45 (6)	.354	<.1
Year of operation, n (%)								
2016	909 (34.7)	204 (28.1)	.002	.149	178 (25.6)	199 (28.6)	.430	<.1
2017	902 (34.4)	262 (36.0)			259 (37.3)	244 (35.1)		
2018	812 (31.0)	261 (35.9)			258 (37.1)	252 (36.3)		
ASA classification, n (%)								
I	10 (.4)	0 (0)	<.001	.297	0 (0)	0 (0)	.902	<.1
II	1204 (45.9)	236 (32.5)			240 (34.5)	232 (33.4)		
III	1385 (52.8)	480 (66.0)			444 (63.9)	452 (65.0)		
IV	24 (.9)	11 (1.5)			11 (1.6)	11 (1.6)		
T2D, n (%)								
Present	691 (26.3)	229 (31.5)	.007	.114	217 (31.2)	216 (31.1)	>.99	<.1
With medication*	1932 (73.7)	498 (68.5)			478 (68.8)	479 (68.9)		
Hypertension, n (%)								
Not present	980 (37.4)	260 (35.8)	.001	.152	232 (33.4)	251 (36.1)	.558	<.1
Present	397 (15.1)	152 (20.9)			148 (21.3)	140 (20.1)		
With medication	1246 (47.5)	315 (43.3)			315 (45.3)	304 (43.7)		
Dyslipidemia, n (%)								
Not present	1245 (47.5)	385 (53.0)	.005	.137	358 (51.5)	363 (52.2)	.964	<.1
Present	420 (16.0)	123 (16.9)			119 (17.1)	117 (16.8)		
With medication	958 (36.5)	219 (30.1)			218 (31.4)	215 (30.9)		
GERD, n (%)								
Not present	2109 (80.4)	616 (84.7)	.010	.132	571 (82.2)	587 (84.5)	.453	<.1
Present	117 (4.5)	33 (4.5)			33 (4.7)	32 (4.6)		
With medication	397 (15.1)	78 (10.7)			91 (13.1)	76 (10.9)		
OSAS, n (%)								
Not present	1922 (73.3)	506 (69.6)	.129	.084	494 (71.1)	487 (70.1)	.918	<.1
Present	362 (13.8)	110 (15.1)			99 (14.2)	102 (14.7)		
With medication	339 (12.9)	111 (15.3)			102 (14.7)	106 (15.3)		
Musculoskeletal pain, n (%)								
Not present	1375 (52.4)	362 (49.8)	.412	.056	353 (50.8)	348 (50.1)	.964	<.1
Present	1222 (46.6)	356 (49.0)			333 (47.9)	338 (48.6)		
With medication	26 (1.0)	9 (1.2)			9 (1.3)	9 (1.3)		

RYGB = Roux-en-Y gastric bypass; SG = sleeve gastrectomy; SMD = standardized mean difference; BMI = body mass index; ASA = American Society of Anesthesiologists; GERD = gastroesophageal reflux disease; OSAS = obstructive sleep apnea syndrome; SD = standard deviation; kg/m^2 = kilogram per square meter; T2D = type 2 diabetes.

* Patients with type 2 diabetes using oral antidiabetic agents, insulin or a combination therapy of insulin and oral antidiabetic agents.

more favorable weight loss outcomes (≥20%TWL) and better metabolic effects regarding dyslipidemia.

There have been several previous retrospective studies comparing T2D remission between bariatric surgical procedures [22–24]. Brethauer et al. [23] showed that RYGB has significantly better T2D remission rates compared with SG or adjustable gastric banding (AGB). In contrast, Jiménez et al. [24] found that RYGB and SG patients have comparable T2D remission rates. The contrasting findings between these studies may be due to pitfalls such as selection bias, heterogeneity in groups, and treatment by indication bias. To adjust for this bias, we used PSM and obtained balanced groups with comparable characteristics. Thus, similar to what would be seen with randomization, the measured baseline covariates are similar between treated and untreated patients, making it possible to obtain an unbiased estimate of the average treatment effect [16]. The analysis of a PSM cohort can mimic that of an RCT, as direct comparisons between outcomes are possible. Our results show statistically significant differences in favor of RYGB compared with SG in terms of T2D remission and are thus a valuable addition to available evidence.

Among 134 patients completing a 5-year follow-up, Schauer et al. [13] showed in the STAMPEDE trial that bariatric surgery was more effective than intensive medical therapy alone, but there was no significant difference in T2D remission rates between SG and RYGB groups. However, their study was limited in the sample size within the

Table 2
Multivariable logistic regression adjusting for confounders to determine the effect of RYGB and SG on T2D remission within 1-year follow-up

Multivariable analysis in T2D remission	T2D complete or partial remission		*P* value
	n (%)*	OR (95% CI)	
Type of procedure			
SG	727 (21.7)	ref.	
RYGB	2623 (78.3)	1.54 (1.14–2.1)	.005
Sex			
Male	1108 (33.1)	ref.	
Female	2242 (66.9)	.96 (.72–1.27)	.770
Age, mean (SD)	51 (9)	.98 (.96–1.0)	.013
BMI, mean (SD)	43 (6)	.99 (.97–1.01)	.246
Yr of operation			
2016	1113 (33.2)	ref.	
2017	1164 (34.7)	.97 (.72–1.3)	.826
2018	1073 (32)	1.76 (1.23–2.53)	.002
ASA Classification			
I/ II	1450 (43.3)	ref.	
III+	1900 (56.7)	2.07 (1.57–2.71)	<.001
T2D			
Present	920 (27.5)	ref.	
With medication	2430 (72.5)	.41 (.27–.61)	<.001
Hypertension			
Not present	1240 (37)	ref.	
Present	549 (16.4)	.83 (.53–1.3)	.418
With medication	1561 (46.6)	.95 (.7–1.28)	.722
Dyslipidemia			
Not present	1630 (48.7)	ref.	
Present	543 (16.2)	1.44 (.92–2.26)	.111
With medication	1177 (35.1)	1.13 (.84–1.51)	.424
OSAS			
Not present	2428 (72.5)	ref.	
Without CPAP	472 (14.1)	1.28 (.84–1.96)	.247
With CPAP	450 (13.4)	.9 (.63–1.28)	.550

T2D = type 2 diabetes; OR = odds ratio; CI = confidence interval; SG = sleeve gastrectomy; RYGB = Roux-en-Y gastric bypass; SD = standard deviation; BMI = body mass index; ASA = American Society of Anesthesiologists; OSAS = obstructive sleep apnea syndrome; CPAP = continuous positive airway pressure.

* The absolute number and percentage are shown for categorical variables and the mean (SD) for continuous variables.

bariatric surgery groups, as their study was not powered to detect differences in outcomes between the 2 techniques. We also have to consider that this is a selected group of patients participating in a trial in a certain region, due to the fact that it is a single-center trial. The SLEEVEPASS trial and the SM-BOSS trial confirmed the aforementioned results among 193 and 205 patients completing 5-year follow-ups, respectively [11,12]. Both these trials were underpowered to detect a difference in T2D remission, as their primary outcome was weight loss. Also, they used a selected group of patients whose data may not be generalizable to the entire population. This emphasizes the need for well-designed trials with larger sample sizes, but also results that can be generalized on a population level. The current matched study, with a large cohort of 695 patients in each surgical technique group, shows that RYGB results in more favorable metabolic remission at 1 year in patients with obesity and T2D. The short-term results for the recently published Oseberg trial were similar with 109 patients [25], supporting the contention that patients with T2D undergoing RYGB may be more likely to achieve T2D remission.

Profound weight loss is known to be associated with higher T2D remission rates [6,7]. In this study, the RYGB group had 2.71 times better odds of achieving ≥20% TWL at the 1-year follow-up. Furthermore, others have shown that similar weight loss results for the 2 treatments will still result in better glycemic control for RYGB patients [26]. This might be due to the metabolic effects of the gastric bypass on multiorgan insulin sensitivity, β-cell functions, and increased metabolic activity of brown adipose tissue, making it less likely for the SG technique to give the same results [27–29].

Together with the favorable metabolic effects of the gastric bypass on T2D, it has also been shown to be associated with higher remission rates in hypertension and

Table 3
Propensity score matched comparison of RYGB and SG on secondary outcome measures at the 1-year follow-up

	OR (95% CI)	*P* value
Primary outcome		
T2D remission	1.91 (1.27–2.88)	<.01
Secondary outcomes		
≥20% TWL	2.71 (1.96–3.75)	<.01
≥50% EWL	3.12 (2.33–4.18)	<.01
Hypertension remission	1.33 (.96–1.84)	.088
Dyslipidemia remission	1.96 (1.39–2.76)	<.01
GERD remission	1.71 (.67–4.35)	.258
OSAS remission	1.09 (.65–1.84)	.733
Musculoskeletal pain remission	1.39 (.92–2.09)	.115
Clavien Dindo ≥III	.57 (.3–1.08)	.083
ICU admission	.32 (.03–3.14)	.331
Length of stay >2 d	.72 (.48–1.06)	.099

RYGB = Roux-en-Y gastric bypass; SG = sleeve gastrectomy; OR = odds ratio; CI = confidence interval; T2D = type 2 diabetes; TWL = total weight loss; EWL = excess weight loss; GERD = gastroesophageal reflux disease; OSAS = obstructive sleep apnea syndrome; ICU = intensive care unit.

SG was used as the reference procedure. Analyses were completed after matching results in balanced groups and were only adjusted for confounding by indication using the propensity score, thereby comparing patients with the same chance of receiving a procedure. Co-morbidity remission is defined as complete remission or partial remission.

dyslipidemia [30–32]. Our study confirms these findings in the matched cohort, with more favorable dyslipidemia remission in the RGYB group.

Despite the risks for severe postoperative complications, bariatric surgery is mostly performed for sustainable weight loss and beneficial metabolic effects, resulting in lower cardiovascular risks, lower mortality, and improved quality of life for the patients in the long run [14,33]. In this study, patients receiving RYGB had similar rates of severe postoperative complications, defined as those with a CD grade ≥III ($P = .083$), in the matched groups. The similar complication rates after RYGB and SG are in line with international findings about postoperative complications in countries with well-established bariatric surgery programs [1,34]. Only 1 patient in the matched SG group had a reoperation for stricture within 1 year of follow-up, whereas the RYGB group had no major complications within 1 year. Several studies have shown that RYGB and SG have similar long term-complication rates within 5 years after bariatric surgery [11,12]. However, as mentioned before, the DATO is an ongoing data collection initiative, and longer-term follow-up data will be collected to examine the overall and longer-term outcomes.

Even though the use of PSM is a strength, there are also several limitations that should be noted. First, 82.4% patients had an outpatient clinic visit between 9 and 15 months postoperatively, meaning 17.6% did not have data for this interval (Fig. 1). The national audit is mandatory and the quality of the data improves over the years, but values missing due to being outside predefined intervals, deceased patients, or logistical reasons (such as health insurance costs) remain challenging for data collection in bariatric surgery. Despite continuous efforts from hospitals to individually contact patients, missing outpatient clinic visits between predefined intervals remain. Secondly, this study could not adjust for unmeasured confounders, such as surgeon preferences, disease severity, or disease duration, where previous studies have shown that these are negatively correlated with T2D remission and differ between RYGB and SG patients [4,35,36]; thus, some residual confounding could remain. Although a trial would exclude the aforementioned confounding, this would include a selected group of patients not generalizable to the whole population. Thirdly, our study only has evaluated short-term results up to the 1-year follow-up. Since obesity is a chronic disease, the impact of bariatric surgery has to be studied across a longer duration of follow-up to draw conclusions on the sustainability of co-morbidity control [37]. As the DATO is an ongoing data collection initiative, the number of patients will increase, and longer-term follow-up results will be collected to examine whether the favorable short-term metabolic effects will be sustained.

Conclusion

Using population-based data from the Netherlands, this study shows that RYGB is associated with more favorable T2D remission and weight loss outcomes at the 1-year follow-up compared with SG. In addition, RYGB shows favorable metabolic effects compared with SG and the 2 procedures have similar outcomes in terms of postoperative complications up to 1 year. Future research should investigate the longer-term outcomes of co-morbidity control in patients with obesity and T2D.

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Disclosures

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

Supplementary materials

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