Bariatric-metabolic surgery for NHS patients with type 2 diabetes in the United Kingdom National Bariatric Surgery Registry

Short running title: Bariatric surgery for patients with type 2 diabetes in the NHS

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Conflict of interest declaration

All authors declare no conflict of interest relevant to this work.

Novelty statement

What is already known:

Bariatric-metabolic surgery has been shown to place T2DM into remission and resolve obesity-associated comorbidities in randomised trials

What this study has found:

The National Bariatric Surgery Registry has shown that patients in the UK national health service have more established disease and a greater number of associated comorbidities compared to other similar healthcare systems

What are the implications of this study:

Patients receiving bariatric-metabolic surgery for severe obesity and T2DM are having the intervention when it is less optimally effective and treatment pathways for patients with severe obesity and T2DM should be improved.

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The paper conforms to the STROBE checklist for an observational cohort study https://www.strobe-statement.org/fileadmin/Strobe/uploads/checklists/STROBE_checklist_v4_cohort.pdf

Guarantor

RW takes responsibility for the integrity of the work and confirms that he controlled the decision to publish**.**

Ethical Approval Statement

For this type of study formal consent is not required.

Informed Consent Statement

Informed Consent does not apply.

Abstract

Aim: Bariatric-metabolic surgery is approved by the National Institute of Health and Care Excellence (NICE) for people with severe obesity and type 2 diabetes (T2DM) (including class 1 obesity after 2014). This study analysed baseline characteristics, disease severity and operations undertaken of people with obesity and T2DM undergoing bariatric-metabolic surgery in the UK National Health Service (NHS) compared to those without T2DM.

Methods: Baseline characteristics, trends over time and operations undertaken were analysed for people undergoing primary bariatric-metabolic surgery in the NHS using the National Bariatric Surgical Registry (NBSR) for 11 years from 2009 to 2019. Clinical practice before and after publication of the NICE guidance (2014) was examined. Multivariate logistic regression was used to determine associations with T2DM status and procedure undertaken.

Results: 14,948/51,715 (28.9%) participants had T2DM, with 10,626 (71.1%) on oral hypoglycaemics,4,322 (28.9%) on insulin/other injectables and diagnosed 10+ years preoperatively in 3,876 (25.9%). Participants with T2DM,compared to those without T2DM, were associated with older age ($p<0.001$), male sex ($p<0.001$), poorer functional status ($p<0.001$), dyslipidaemia (OR:3.58(CI: 3.39-3.79); $p<0.001$), hypertension (OR: 2.32(2.19-2.45); $p<0.001$) and liver disease (OR: 1.73(1.58-1.90); $p<0.001$) but no difference in body mass index was noted. Fewer patients receiving bariatric-metabolic surgery after 2015 had T2DM ($p<0.001$), although a very small percentage increase of those with class I obesity and T2DM was noted. Gastric bypasses were the commonest operation for all patients. T2DM status was associated with selection for gastric bypass compared to sleeve gastrectomy ($p<0.001$).

Conclusion: NHS bariatric-metabolic surgery is used for patients with T2DM much later in the disease process when it is less effective. National guidance on bariatric-metabolic surgery and data from multiple RCTs have had little impact on clinical practice.

Abstract: 243 words

Keywords: Obesity, Type 2 Diabetes Mellitus, Bariatric Surgery, Gastric bypass, Registries

Introduction

National Diabetes Audit data demonstrate that in England, 90% of adults living with type 2 diabetes mellitus (T2DM) aged 16-54 years also have obesity[1]. People with severe obesity and T2DM can benefit from surgical intervention, in addition to lifestyle modification and pharmacotherapy[2, 3]. The term bariatric surgery is often used interchangeably with 'metabolic' surgery where the purpose is treatment of obesity and co-existent metabolic disease such as T2DM. 'Bariatric-metabolic' surgery is now often used to describe this area of surgery[4-7]. Bariatric-metabolic surgery has been shown in the Swedish Obese Subjects (SOS) study and several randomised controlled trials (RCTs) to result in better glycaemic control and higher rates of T2DM remission[8] compared to best medical treatment with less medication use. Surgery is also associated with a reduction in the incidence of cardiovascular disease, macro- and microvascular complications and mortality in T2DM compared to best medical treatment[9-13]. Examples of bariatric-metabolic procedures include diversionary operations Roux-en-Y gastric bypass (RYGB), one anastomosis gastric bypass (OAGB); and vertical sleeve gastrectomy (VSG)[4].

Multiple United Kingdom (UK) guidelines describe criteria for offering bariatric-metabolic surgery to people with T2DM. The National Institute of Health and Care Excellence (NICE), a UK public body that provides national guidance and advice to improve health and social care, recommended in 2006 that bariatric-metabolic surgery be offered to patients with body mass index (BMI) 40kg/m^2 or 35kg/m^2 with a comorbidity that could improve with weight loss[14]. In updated guidance, NICE indicated that people with T2DM diagnosed within 10 years and BMI 30-34.9kg/m^2 (class I obesity) should be offered an expedited assessment for surgery (2014)[15]. The BMI threshold for consideration of surgical assessment was lowered from 35kg/m^2 to 30-34.9kg/m^2 and lowered further for people of specific ethnic groups. NICE-accredited commissioning guidance (2016)[16] endorsed by 10 royal colleges and specialist organisations (expanded to 22 in 2017)[17] also supported the new thresholds. International position statements and guidelines including those from the International Disease Federation (IDF)[18] and the second Diabetes Surgery Summit (DSS) (2016)[19] recommended surgery as an option to treat T2DM for people with BMI≥40 kg/m^2 as well as in patients with BMI 35-34.9kg/m^2 with inadequately controlled disease. The DSS also lowered the BMI threshold to 30kg/m^2. The DSS guidelines are endorsed by over 50 international organisations.

The impact of this evolving guidance on the use of bariatric-metabolic surgery in the National Health Service (NHS), the public healthcare system in the United Kingdom, over time is unknown. Other knowledge gaps include the baseline characteristics and stage of T2DM in people aged 18 or over having primary bariatric-metabolic surgery in the NHS, and the types of operation undertaken. Our primary aim was to describe these, using the UK and Republic of Ireland National Bariatric Surgery Registry (NBSR). Secondary aims were to describe the proportions of T2DM in different BMI ranges and procedure selection over time.

Methods

The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)[20] guidance.

Study setting

Data from the NBSR were utilised for this study as described previously[21]. Briefly, the NBSR is a prospectively collected nationwide registry of all bariatric-metabolic surgical procedures undertaken in the UK and Republic of Ireland comprising preoperative, operative and follow-up data.

Study population

51,715 people who underwent primary bariatric surgery within the NHS over 11 years from the start of the NBSR in January 2009 to December 2019 were included in the study. Participants were excluded if they were less than 18 years of age, were undergoing revisional surgery (defined as a conversion to another bariatric procedure) or insertion of a gastric balloon as the only treatment, or if their surgery was not undertaken within the NHS.

Data collection and outcomes

Data regarding preoperative demographic characteristics, anthropometrics, presence of comorbidities (T2DM, liver disease, cardiovascular disease, gastro-oesophageal reflux disease (GORD), asthma, hypertension, dyslipidaemia, arthritis, and depression), comorbidity treatment, ethnicity, date of surgery and operation undertaken were examined. The disease stage options for T2DM in the dataset were: no indication of type 2 diabetes; impaired glycemia or impaired glucose tolerance; oral glucose-lowering medications; and insulin treatment or other injectable therapy. Disease duration was recorded and categorised according to years, with responses over 10 years coded together as 10 years or more. HbA1c was not included in the NBSR dataset until 2019 and was not included in this study. Participants were recorded as been diagnosed with T2DM or hypertension when they required one or more medication for either condition. Patients reporting reflux symptoms or taking intermittent or daily medication for gastro-oesophageal reflux disease (GORD) were recorded as having GORD. Baseline overall disease staging was assessed by the American Society of Anaesthesiologists (ASA) grade; Obesity Surgery-Mortality Risk Score (OS-MRS); and Edmonton Obesity Staging System (EOSS). The Obesity Surgery-Mortality Risk Score combines age, sex, BMI hypertension and known VTE risk and predicts perioperative mortality[22]. The Edmonton Obesity Staging System (EOSS) predicts long-term mortality according to severity of baseline obesity-related disease[23] and the NBSR dataset has been used to calculate the EOSS previously[24] (Supplementary table 1). A diagnosis of "depression on medication" was used as a surrogate for mental health disorder. Data were analysed from 2009 to 2014 and from 2015 to 2019 to examine the impact of the 2014 updated NICE guidance on the use of bariatric-metabolic surgery in T2DM and class I obesity[15].

Procedure types were recorded including Roux-en-y gastric bypass (RYGB), sleeve gastrectomy (SG), gastric banding (GB) and one-anastomosis gastric bypass (OAGB). Associations between T2DM status and procedure type were examined using multinomial logistic regression with sleeve gastrectomy taken as the reference procedure as it is the most common bariatric-metabolic surgery operation type globally[4].

Statistical analysis

Patient demographic and clinical characteristics were compared across groups using the Pearson χ^2 test for categorical nominal data and Mann-Whitney U for continuous data. Univariate and multivariate logistic regression models identified factors associated with T2DM status, with results reported using Odds Ratios (OR) and 95% confidence intervals (CI). Comparison of baseline factors and outcomes by procedure were initially carried out by analysis of variance or χ^2 tests as appropriate. Further adjusted comparison of factors associated with different procedure selection was conducted using multinomial logistic regression. For procedure type, sleeve gastrectomy was chosen as the reference category. Statistical analyses were undertaken using SPSS version 25 (IBM, Chicago, Illinois, USA). $P < 0{\cdot}05$ was considered statistically significant.

Results

51,715 people recorded in the NBSR undergoing primary bariatric surgery in the NHS over 11 years between 1/1/2009 and 31/12/2019 were included in the analysis (Table 1, Fig. 1). 14,948 (28.9%) had T2DM at the time of surgery, of which 10,626 (71.1%) were on oral glucose-lowering medication and 4,322 (28.9%) were on insulin or other injectable therapy (Table 1). The proportion of people with T2DM undergoing bariatric-metabolic surgery was significantly reduced after 2014 (pre-2014: 8171/33632 (24.2%) vs 2014-2019: 11,042/51,668 (21.4%); p<0.001) (Fig. 2). 3,876 (25.9%) had T2DM for 10 years or more before surgery. Those with longer duration T2DM were more likely to be on insulin (p<0.001) (Supplementary fig. 1).

Comparison of people with and without T2DM undergoing bariatric-metabolic surgery

Baseline characteristics of people with and without T2DM are compared (Table 1). On multivariate adjustment, people with T2DM were mean 6.5 years older and more likely to be male, have a higher ASA grade, worse functional status, and higher rates of hypertension, dyslipidaemia, cardiovascular disease, and sleep apnoea (Table 2). People with T2DM were more likely to have an elevated ASA scare and OS-MRS grade. The difference in BMI between those with and without T2DM was small. However, men with T2DM underwent surgery at a lower BMI compared to those without T2DM (Supplementary fig. 2).

Trends over time

There was minimal change in the BMI classes of people undergoing bariatric-metabolic surgery (Supplementary fig. 3). Overall, the proportions of people with BMI 35-40kg/m^2 increased over time (p<0.001). The proportion of people with T2DM and BMI 30-35kg/m^2 also increased slightly from around 3% prior to 2014 to 7% from 2014 onwards (p<0.001).

Procedure type

The type of procedure changed for both T2DM and non-T2DM people over time (Fig. 3). There was a reduction in use of gastric banding and an increase in VSG for both groups. In people with T2DM, RYGB remained the commonest procedure (approximately 50% of operations by the end of the study), with one-third undergoing sleeve gastrectomy from 2016 onwards. The prevalence of OAGB increased significantly over time ($p<0.001$) and was used slightly more in those with T2DM (OR 1.57 (1.35-1.82); $p<0.001$). In those without T2DM, the proportion having sleeve gastrectomy increased to 40.5% compared to 44.7% for RYGB by the end of the study.

Associations with type of bariatric-metabolic surgery procedure undertaken

When sleeve gastrectomy was taken as the reference procedure, RYGB and OAGB were significantly more likely to be performed in people with T2DM (Table 3), and gastric banding was significantly less likely to be performed. For both RYGB and OAGB there did not appear to be a significant effect of BMI after adjustment for other factors, whereas gastric banding was more likely to be performed in those with BMI 30-35kg/m^2 and less likely in those with BMI of 40kg/m^2 or more.

Discussion

This NBSR dataset has demonstrated that bariatric-metabolic surgery in people with severe obesity and T2DM is frequently used late in the disease course in the NHS and often when participants have established complications, associated comorbidities and are on insulin. Despite guidelines that have strengthened recommendations and lowered the BMI thresholds, fewer people with T2DM are having bariatric-metabolic surgery in the UK [15, 19]. Taken together, there has been little change in use of bariatric-metabolic surgery in the NHS despite national increases in the prevalence of obesity and T2DM. There has been no substantial increase in operations undertaken for patients with recent-onset T2DM in the lowest BMI category approved for surgery (30-35kg/m^2) after the 2014 NICE guidance, albeit with very few being done prior to 2014. For people with T2DM undergoing surgery, the diversionary bypass operations RYGB and OAGB were more likely to be performed than sleeve gastrectomy or gastric banding.

Comparison of the UK NBSR with other national registries demonstrates differences in population characteristics. In the Swedish bariatric surgery registry, people with T2DM had a mean BMI of 42.2kg/m^2, as few as 10% of them were diagnosed 10 years or more prior to surgery and 23% were on dietary and lifestyle treatment alone with 28% receiving insulin[25]. These findings contrast with the data from our study, where people with T2DM have higher BMI, are older, with more comorbidities and are more often already on insulin. This indicates that in the NHS people undergo bariatric-metabolic surgery with more advanced and established disease than patients in Sweden, which has a similarly structured health service. Multiple studies including RCTs indicate that people on insulin or who have longer duration of T2DM diagnosis at the time of surgery, such as seen in this study of NHS practice, have a reduced likelihood of achieving remission[10-12, 26, 27]. Use of bariatric-metabolic surgery with shorter T2DM disease duration would likely lead to reduced patient treatment burden and higher rates of T2DM remission. From the health system perspective, bariatric-metabolic surgery for people with T2DM and severe obesity has been reported as cost-effective and may even be cost-saving over longer time horizons[21, 28].

Possible reasons why bariatric-metabolic surgery appears to be used only in the later stages of T2DM include obesity stigma in healthcare professionals that could disadvantage people with obesity accessing evidence-based care[29]; lack of participant [30] and primary care clinician[31, 32] awareness of bariatric-metabolic surgery as a therapeutic option in T2DM, concerns about surgical complications[33] and variation in bariatric surgery commissioning influencing referral rates for surgery. A study of primary care clinicians reported little understanding of the role of bariatric-metabolic surgery despite the wide-ranging impact obesity has on physical and mental health issues[32]. Whilst surgical risk following bariatric-metabolic surgery is reported as a concern by non-obesity clinicians[33], the mortality rate following bariatric-metabolic surgery is lower than cholecystectomy[34], which is one of the most commonly performed abdominal operations in the NHS[35]. Studies previously performed in the UK indicate variation in both regional bariatric-metabolic surgery provision[36] and in commissioning criteria[37] which in some cases did not follow NICE guidance, which may explain the limited delivery in the NHS.

Use of bariatric-metabolic surgery in people with BMI 30-35kg/m^2 remained low across the period of our study with a small change noted after 2014 following the updated NICE guidance and the NICE-accredited commissioning guidance [17]. There is a paucity of published national level data examining the delivery of bariatric-metabolic surgery for patients with T2DM and BMI 30-35kg/m^2. This study indicates that national and international guidance have had no discernible impact on clinical practice.

Diversionary bariatric-metabolic surgery (RYGB and OAGB) was significantly more likely to be used in those with T2DM. This contrasts with international practice, where the IFSO Global Registry indicates that sleeve gastrectomy is the predominant operation[4]. At least 4 RCTs have compared RYGB with sleeve gastrectomy [10, 38-40]. Recently published long-term RCT data from the SLEEVEPASS trial shows no difference in likelihood of T2DM remission between RYGB and sleeve gastrectomy[41]. Only the Oseberg RCT[40] of those comparing RYGB and sleeve gastrectomy had T2DM remission as a primary endpoint and favoured RYGB for glycaemic control. Additionally, data from the SOS study has shown that degree of weight loss and not operation type is a key determinant of T2DM remission[42]. Despite these differing observations, it appears that the clinician and participant perception in NHS practice continues to be to prefer RYGB or OAGB in those with T2DM.

The study has several strengths including high case ascertainment of over 95% compared to routinely collected NHS administrative data, and the data are from the UK NBSR, a comprehensive data registry with mandatory annual reporting[43]. Limitations include the lack of data fields in the NBSR dataset to record whether a participant chooses to have bariatric-metabolic surgery for obesity or T2DM management, or for other reasons. Secondly, recording of HbA1c haemoglobin was only incorporated into later versions of the NBSR dataset and so was not available for the whole of the study period and, therefore, it was not considered in this study. Thirdly, the recording of glucose-lowering medications is limited to insulin therapy, and specific other injectable glucose-lowering agents were not recorded. A recent RCT suggests adding other glucose-lowering agents improves outcomes after bariatric surgery[44]. Finally, the NBSR does not record primary care interactions including discussions regarding referral for bariatric-metabolic surgery and patient acceptance of this. Small studies conducted in this area suggest around a quarter to half of eligible patients would consider bariatric-metabolic surgery[45, 46]. However, the UK performs considerably less bariatric-metabolic surgery per capita than our global comparators[47] and there is no evidence that the UK population is less accepting of surgery for T2DM and obesity. Clarifying patient acceptance of bariatric-metabolic surgery for T2DM is an important area of future study.

Prior research using routinely collected datasets has demonstrated that only 0.2% (6500 operation/year) of eligible English patients receive NHS-funded bariatric-metabolic surgery[36, 47]. This compares with over 50,000 bariatric-metabolic surgical operations annually in France[47, 48] which has a lower population level of both T2DM and obesity. Further work should explore the reasons for limited treatment intensification for people with severe obesity and T2DM in the NHS.

Conclusion

This NBSR study has uniquely shown that bariatric-metabolic surgery for people in the NHS with obesity and T2DM is frequently used late in illness and when there is more associated comorbidity indicating impaired treatment intensification. Multiple RCTs and international position statements and guidelines advocating for increased delivery of bariatric-metabolic surgery appeared to have had minimal effect for NHS patients with obesity and T2DM. The increasing availability of effective medications for obesity and T2DM and combination therapy with bariatric-metabolic surgery points to a more positive future for affected people. Closer working between the bariatric-metabolic surgery and diabetology communities should focus on increasing the access to evidence-based bariatric-metabolic surgical interventions for people with severe obesity and T2DM.

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TABLE 1. Baseline characteristics and risk scores of NHS patients with and without T2DM undergoing primary bariatric surgery in the NBSR (n=51,715). N (%) unless specified. BMI, body mass index; T2DM, type 2 diabetes mellitus; OSA, obstructive sleep apnoea; VTE, venous thromboembolism; GORD, Gastro-oesophageal reflux disease; PCOS, Polycystic Ovary Syndrome; ASA, American Society of Anaesthesiologists; OS-MRS, Obesity Surgery-Mortality Risk Score; EOSS, Edmonton Obesity Staging System. Comorbidities are % on daily medication or treatment.

		T2DM (n=14948)	Non-T2DM (n=36767)	P-value
Mean age (years) ± SD		49.9 ± 9.8	43.4 ± 11.3	<0.001
Age distribution (years)	18 – 30	465 (3.1%)	4851 (13.2%)	<0.001
	31 – 40	2023 (13.5%)	9311 (25.3%)	
	41 – 50	5059 (33.8%)	12179 (33.1%)	
	51 – 60	5356 (35.8%)	8152 (22.2%)	
	60+	2045 (13.7%)	2274 (6.2%)	
Sex (male)		5085 (34.0%)	7032 (19.1%)	<0.001
Caucasian ethnicity		12061 (83.2%)	30089 (84.6%)	<0.001
Mean initial BMI (kg/m^2) ± SD		48.0 ± 7.8	49.3 ± 7.8	<0.001
Initial BMI distribution (kg/m^2)	< 35	226 (1.5%)	209 (0.6%)	<0.001
	35 - 39.9	1804 (12.2%)	2632 (7.2%)	
	40 - 49.9	7449 (50.4%)	18530 (50.3%)	
	≥50	5313 (35.9%)	15258 (41.9%)	
Duration of T2DM (years)	≤1	1677 (11.2%)	-	
	2-5	6073 (40.6%)	-	
	6-9	2623 (17.5%)	-	
	≥10	3876 (25.9%)	-	
Asthma		3102 (21.2%)	7617 (21.1%)	0.984
Cardiovascular disease		1565 (10.7%)	1280 (3.6%)	<0.001
Depression		4147 (27.7%)	9772 (26.6%)	<0.001
GORD		3779 (26.6%)	8372 (23.9%)	<0.001
Hypertension		9682 (64.9%)	10927 (29.8%)	<0.001
Liver disease		1628 (11.4%)	1849 (5.3%)	<0.001
Musculoskeletal pain		5020 (34.5%)	11190 (31.3%)	<0.001
OSA		4995 (33.6%)	8503 (23.2%)	<0.001
PCOS		1043 (11.0%)	3312 (11.7%)	0.092
VTE risk factors		2862 (19.6%)	6210 (17.3%)	<0.001
Functional status				
Wheelchair / housebound		582 (4.0%)	987 (2.8%)	<0.001
Can manage ½ flight stairs		3348 (23.1%)	5892 (16.5%)	
Can manage 1 flight stairs		7335 (50.5%)	17814 (50.0%)	
Can manage 3 flight stairs		3248 (22.4%)	10943 (30.7%)	
ASA grade	III	7339 (49.5%)	10335 (28.1%)	<0.001
	IV	190 (1.3%)	155 (0.4%)	
OS-MRS score	Low Risk (0-1)	3991(29.0%)	19258 (57.1%)	<0.001
	Moderate Risk (2-3)	8356 (60.8%)	13080 (38.8%)	
	High Risk (4-5)	1394 (10.1%)	1410 (4.2%)	

EOSS stage*	Stage 0	-	3161 (9.6%)	<0.001
	Stage 1	-	3429 (10.4%)	
	Stage 2	11752 (86.7%)	24518 (74.2%)	
	Stage 3	1265 (9.3%)	1029 (3.1%)	
	Stage 4	538 (4.0%)	888 (2.7%)	

* T2DM diagnosis means EOSS 2 stage is minimum

TABLE 2. Multivariate logistic regression of factors associated with having T2DM in NHS patients in the NBSR. OR, odds ratio; CI confidence interval; Ref, reference; BMI, Body Mass Index; OSA, Obstructive Sleep Apnoea; VTE, venous thromboembolism; GORD, Gastro-oesophageal Reflux Disease. Impaired functional status defined as inability to climb 3 flights of stairs.

		Adjusted OR	CI (95%)	P-value
Age at surgery (years)	18-30	(Ref)		
	31-40	1.83	1.60-2.08	<0.001
	41-50	2.49	2.20-2.82	<0.001
	51-60	2.93	2.58-3.34	<0.001
	60+	3.33	2.88-3.85	<0.001
Gender	Male	1.59	1.50-1.69	<0.001
Ethnicity	Caucasian	(Ref)		
	African/Afro-Caribbean	1.06	0.93-1.20	0.379
	Asian	1.49	1.30-1.71	<0.001
	Chinese	0.96	0.20-4.51	0.958
	Other/Not Recorded	1.15	1.04-1.37	0.008
Initial BMI (kg/m^2)	< 35	(Ref)		
	35-39.9	0.57	0.43-0.75	<0.001
	40-49.9	0.36	0.27-0.47	<0.001
	≥50	0.30	0.23-0.39	<0.001
Medical conditions	Asthma	0.99	0.93-1.05	0.700
	Cardiovascular Disease	1.02	0.92-1.13	0.713
	Depression	0.997	0.996-0.998	<0.001
	Dyslipidaemia	3.58	3.39-3.79	<0.001
	GORD	0.95	0.90-1.01	0.088
	Hypertension	2.32	2.19-2.45	<0.001
	Liver disease	1.73	1.58-1.90	<0.001
	Musculoskeletal pain	0.86	0.81-0.91	<0.001
	OSA	1.06	1.00-1.12	0.058
	VTE risk factors	1.03	0.96-1.10	0.408
Impaired functional status	Can't climb 3 flight of stairs or more	1.19	1.12-1.27	<0.001

Table 3. Multinomial regression of the associations of T2DM and BMI on procedure type in NHS patients in the NBSR. Adjusted for age, ethnicity, comorbidity and year of surgery. OR, odds ratio; CI confidence interval; Ref, reference; BMI, Body Mass Index. Reference procedure: Sleeve gastrectomy.

		ROUX-EN-Y GASTRIC BYPASS		GASTRIC BANDING		ONE-ANASTOMOSIS GASTRIC BYPASS	
		OR (95% CI	p	OR (95% CI	p	OR (95% CI	p
T2DM	Present	1.55 (1.46-1.67)	<0.001	0.88 (0.79-0.98)	0.020	1.57 (1.35-1.82)	<0.001
Initial BMI (kg/m^2)	< 35	1.04 (0.76-1.42)	0.808	1.65 (1.04-2.60)	<0.001	0.68 (0.30-1.58)	0.373
	35-39.9	Ref		Ref		Ref	
	40-49.9	1.1 (1.01-1.21)	0.036	0.58 (0.51-0.67)	<0.001	1.02 (0.82-1.27)	0.843
	≥50	0.93 (0.85-1.02)	0.136	0.31 (0.27-0.36)	<0.001	0.93 (0.74-1.16)	0.526

Figure 1. Case selection for study patients within NBSR.

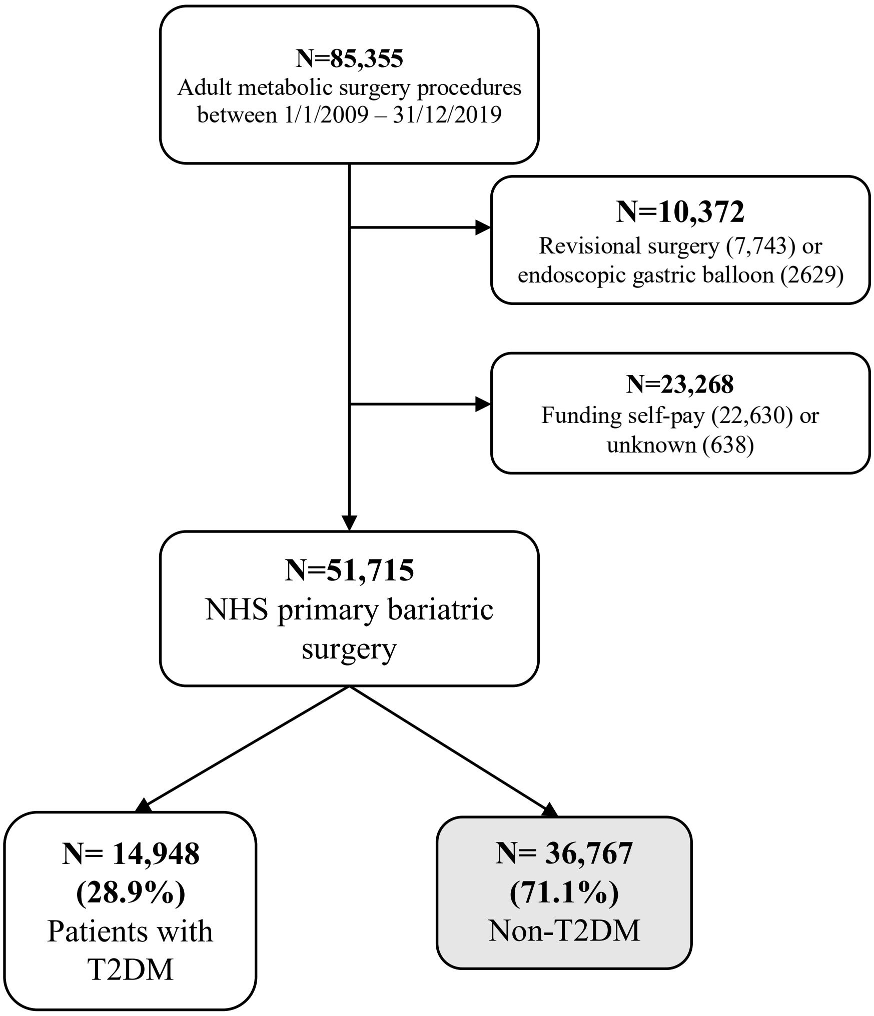


Figure 2. Trend in proportion of NHS patients with and without T2DM in the NBSR.

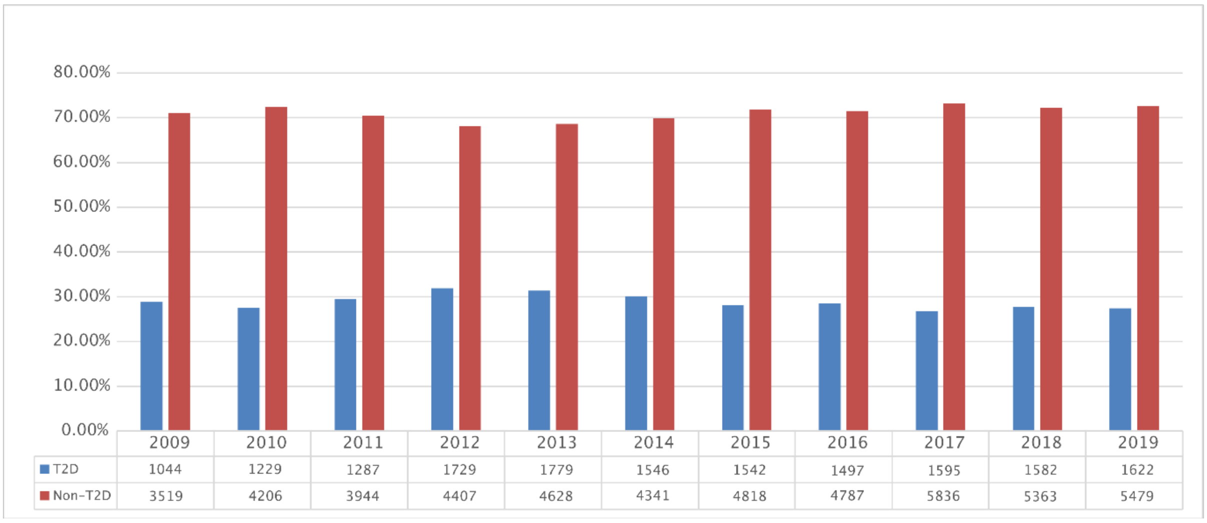
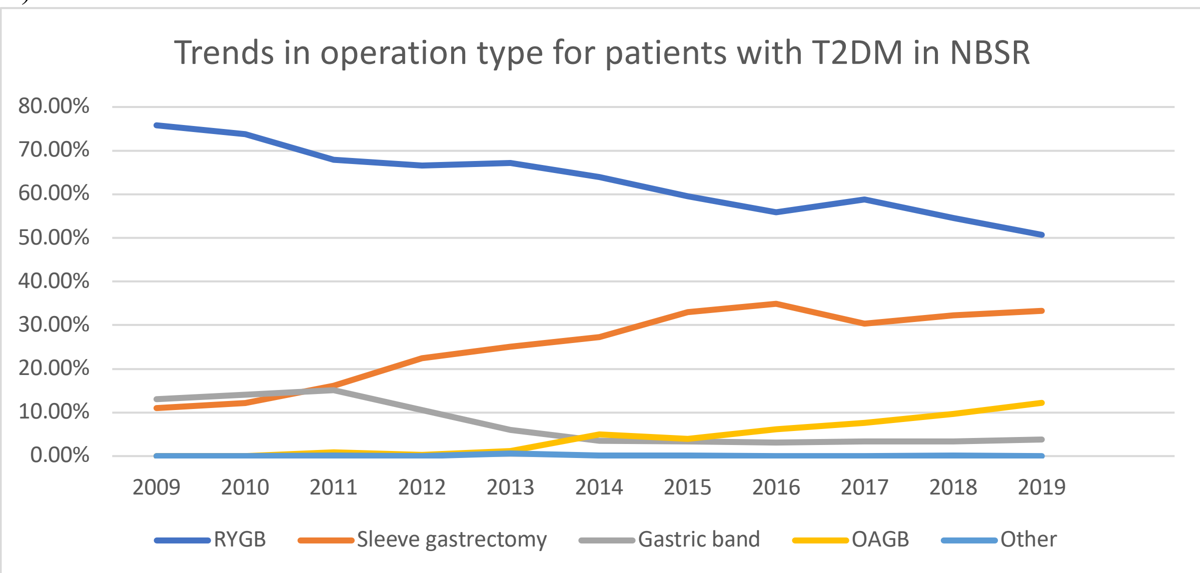


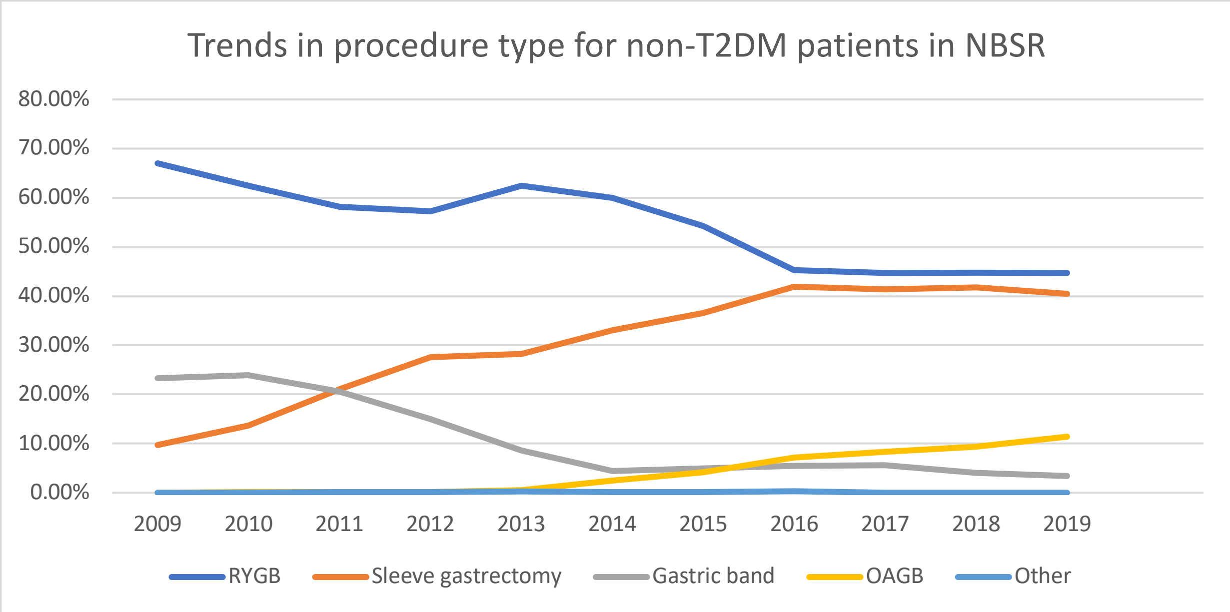
Figure 3. Trends in procedure type for A) patients with T2DM, and B) patients without T2DM in the NBSR.

A) T2DM



	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2017**	**2018**	**2019**
Roux-en-y gastric bypass	764	889	856	1131	1173	965	896	827	898	816
Sleeve gastrectomy	110	150	213	390	454	436	521	528	509	528
Gastric banding	170	190	207	201	122	63	60	50	62	66
One anastomosis gastric bypass	0	0	9	7	20	78	60	92	124	168
Other	0	0	2	0	10	4	5	0	2	4

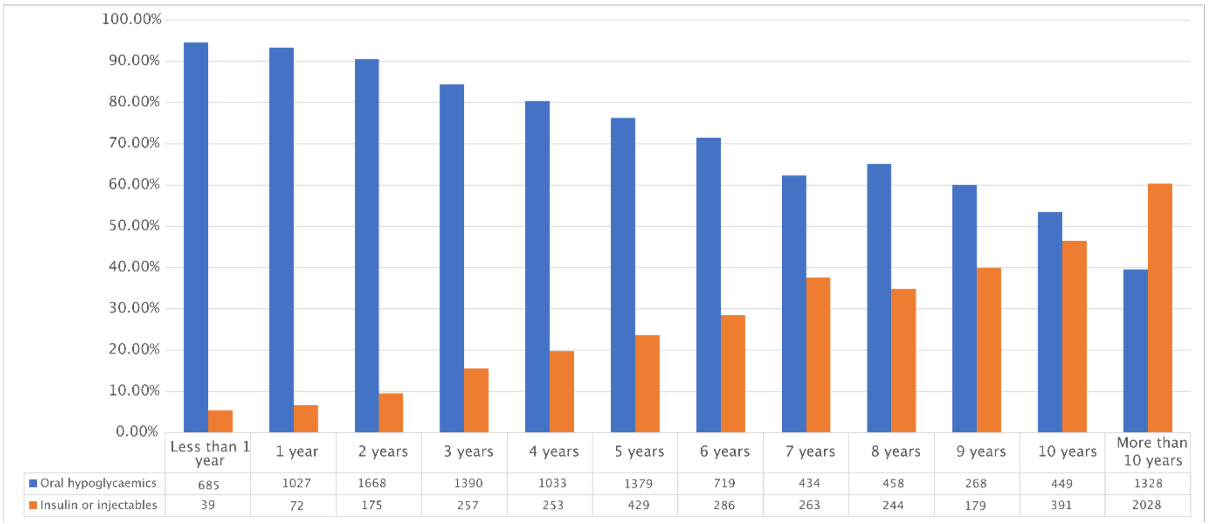
B) non-T2DM



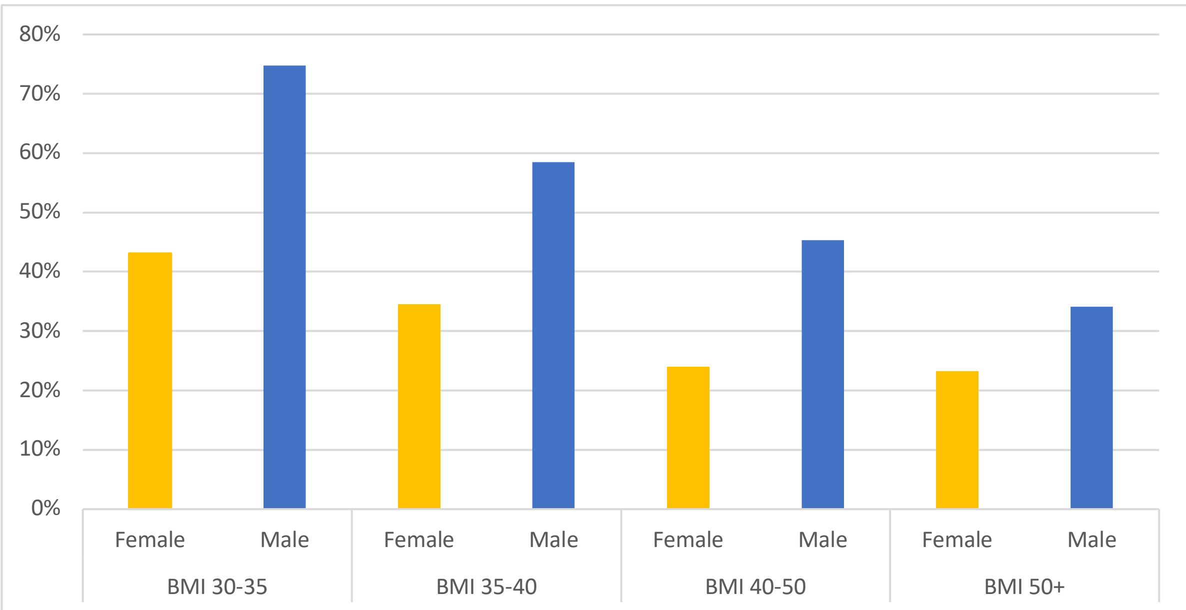
	2009	2010	2011	2012	2013	2014	2015	2017	2018	2019
Roux-en-y gastric bypass	1946	2213	1975	2252	2572	2221	2248	1845	2061	1908
Sleeve gastrectomy	284	584	806	1229	1352	1507	1811	2044	2606	2427
Gastric banding	1288	1406	1149	909	662	497	574	574	727	521
One anastomosis gastric bypass	0	2	4	9	25	95	170	295	418	481
Other	1	1	10	8	17	21	15	29	24	26

Supplementary figures

Supplementary figure 1. Trends in duration and medication usage of T2DM for patients with T2DM in the NBSR, with n values.

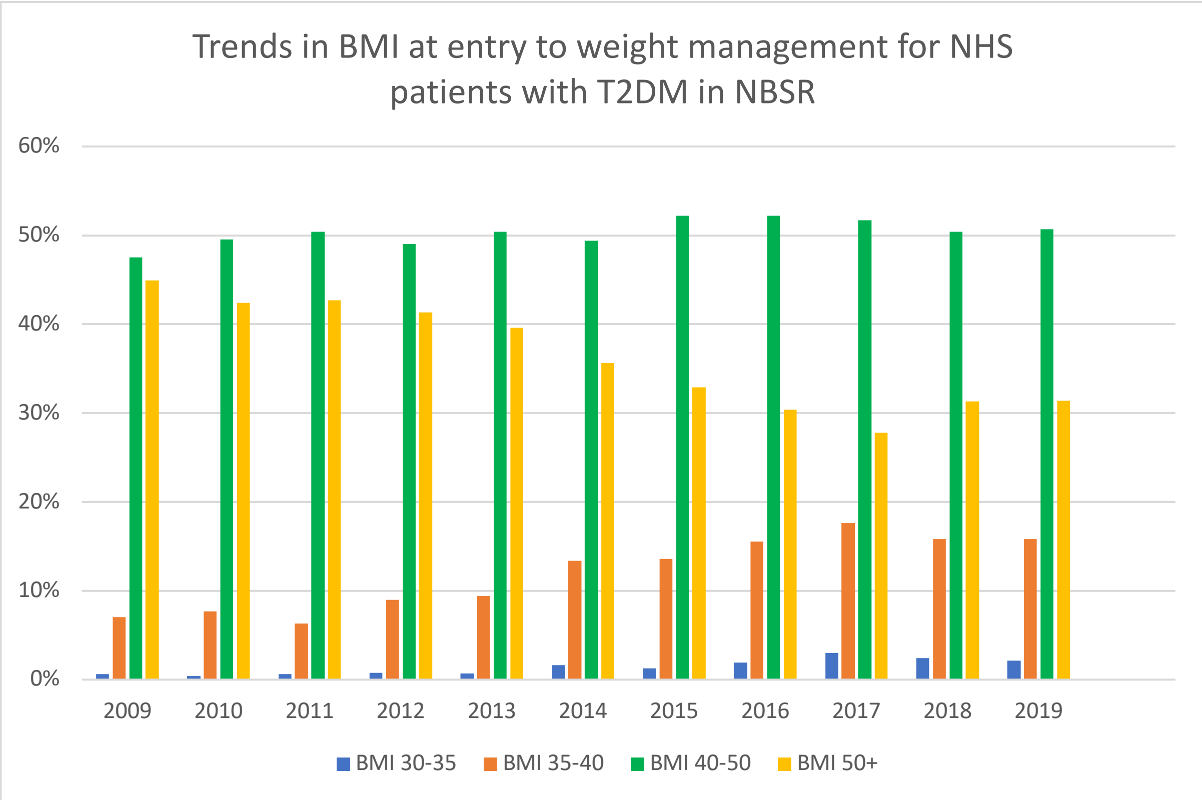


Supplementary figure 2. Proportion of patients with T2DM according to sex and BMI category at entry to weight management.



Supplementary figure 3. Trends in BMI at entry to weight management programme for A) patients with T2DM, and B) patients without T2DM in NHS patients in the NBSR.

A) T2DM



B) Non-T2DM