Pregnancy outcomes following different types of bariatric surgery: a national cohort study

Katie Cornthwaite, MRCOG[a, b], Chetan Prajapati, PhD[b], Erik Lenguerrand, PhD[b], Marian Knight, DPhil, FRCPE[c], Natalie Blencowe, MRCS, PhD[d], Andrew Johnson, MD, FRCP[e], Tim Draycott, MD, FRCOG[a], Dimitrios Siassakos, MD, FRCOG[f,g,h]

[a] Women's Health Department, North Bristol NHS Trust, UK

[b] Translational Health Sciences, University of Bristol, UK

[c] National Perinatal Epidemiology Unit, University of Oxford, UK

[d] Population Health Sciences, University of Bristol, UK

[e] Diabetes and Endocrinology Department, North Bristol NHS Trust, UK

[f] Elizabeth Garett Anderson Institute for Women's Health, University College London, UK

g NIHR Biomedical Research Centre at University College London Hospital

h Wellcome/EPSRC centre for Surgical and Interventional Sciences (WEISS)

Corresponding author

Dr Katie Cornthwaite

The Chilterns

North Bristol NHS Trust

Westbury-on-Trym

Bristol

BS10 5NB

Tel: 07834597324

Email: kc17995@bristol.ac.uk

Abstract

Objective

To assess the impact of type of bariatric surgery on pregnancy outcomes.

Study design

This is a national prospective observational study using the UK Obstetric Surveillance System (UKOSS). Data collection was undertaken in 200 consultant-led NHS maternity units between November 2011 and October 2012 (gastric banding), and April 2014 and March 2016 (gastric bypass and sleeve gastrectomy).

Participants were pregnant women following gastric banding (n=127), gastric bypass (n=134) and sleeve gastrectomy (n=29).

Maternal and perinatal outcomes were compared using generalised linear and linear mixed models. Maternal outcomes included gestational weight gain, pre-eclampsia, gestational diabetes, anaemia, surgical complications. Perinatal outcomes included birthweight, small / large for gestational age (SGA/LGA), preterm birth, stillbirth.

Results

Maternal: Women pregnant after gastric banding and sleeve gastrectomy had a lower risk of anaemia compared with gastric bypass (banding (16%) vs bypass (39%): p=0.002, sleeve (21%) vs bypass: p=0.04). Gestational diabetes risk was lower after gastric banding compared with gastric bypass (7% vs 16%, p=0.03) despite women with banding having significantly greater weight at booking as well as gestational weight gain. Women pregnant after gastric banding and sleeve gastrectomy had a lower risk of surgical complications than after gastric bypass (banding (0.9%) vs bypass (11.4%): p=0.03, sleeve (0.0%) vs bypass: p=0.06).

Perinatal: Infants born to mothers after gastric banding had a higher birthweight than those born to mothers after gastric bypass (mean difference=260g (125-395), p<0.001). Infants were more likely to be LGA if their mothers had gastric banding compared with gastric bypass or sleeve gastrectomy (banding (21%) vs bypass (5%): p=0.006; banding vs sleeve (3%): p=0.03). Risk of preterm birth was higher in women with gastric banding compared with gastric bypass (13% vs 8%, p=0.04).

Conclusions

Women planning bariatric surgery should be counselled regarding the differing impacts of different types of procedure on any future pregnancy. Pre-existing gastric bypass is associated with higher rates of potentially serious surgical complications during pregnancy.

Keywords

Pregnancy, bariatric surgery, bypass, banding, sleeve, cohort

1. Introduction

One in five pregnant women in the UK have a BMI >30 and at least 5% have a BMI >35.[1,2] The adverse consequences of obesity on maternal and perinatal health are well established.[3–6] Weight loss can mitigate these risks and is increasingly being achieved with bariatric surgery.[7] In the UK, over 75% of weight loss operations are in women of childbearing age.[8] Pregnancy after bariatric surgery is now more common,[9] but the preference for type of surgery has changed over time, with sleeve gastrectomy increasingly popular.[10,11]

Evidence from observational studies and systematic reviews has highlighted the benefits of bariatric surgery in reducing obesity-related pregnancy complications such as gestational diabetes.[9,12–14] However, improvements in some maternal outcomes may be at the expense of fetal wellbeing, with higher rates of small for gestational age (SGA) infants and preterm labour in pregnancies following bariatric surgery.[9,12–14] Most studies have conflated different types of bariatric surgery when evaluating pregnancy outcomes, or examined retrospectively cohorts of women spanning several years and likely receiving different care over time (Table 1). However, there are mechanistic differences between bariatric procedures (Figure 1), which are likely to have distinct effects on the mother and fetus. The impact of different types of bariatric surgery on pregnancy outcomes are unclear and conflicting.[9,14–16]

It is essential that healthcare professionals involved in the care of women of reproductive age understand the impact of different types of bariatric surgery on future pregnancy outcomes.[17] Using a nationwide obstetric surveillance system

(UKOSS), we investigated the procedure-related impact of bariatric surgery on pregnancy outcomes in distinct national cohorts.

2. Materials and Methods

2.1. Study design

National prospective observational study of women pregnant after gastric band, bypass and sleeve. Women were identified through the UK Obstetric Surveillance System (UKOSS)[18] in which all 200 consultant-led UK maternity units participate. Nominated clinicians in each unit reported cases and completed a customised, anonymous, data collection form using routinely collected data (https://www.npeu.ox.ac.uk/ukoss/methodology).

2.2. Study population

A cohort study of women pregnant with gastric banding was undertaken between November 2011 and October 2012. Outcomes of these pregnancies, according to band management (inflation versus deflation), are published in detail elsewhere.[19]

To understand pregnancy outcomes after other types of bariatric surgery and given the change in preference for type of surgery, a separate cohort of pregnant women who had undergone bypass surgery was collected between April 2014 and March 2016. This cohort was divided into women with gastric bypass (Roux-en-Y, loop and unspecified bypass) and sleeve. Women with undefined bariatric surgery were excluded. Cases of biliopancreatic diversion and duodenal switch were removed since they are associated with more profound malabsorption and are now rarely performed.[20] We also removed cases with missing outcome data from comparative analyses, as well as multifetal pregnancies due to their differing gestation, fetal growth and complication rates.

2.3. Outcomes and covariates

Maternal outcomes were gestational weight gain (GWG) (kg), BMI change (kg/m^2), gestational hypertension, pre-eclampsia, gestational diabetes (GDM), anaemia, induced labour, mode of birth (vaginal or caesarean), surgical complications, major medical complications, and maternal death. GWG and BMI change were derived from the difference between the first (booking) and late third trimester measurements. Hypertensive disorders and anaemia diagnosed during pregnancy were as defined by the reporting hospital. Surgical complications included surgical procedure in pregnancy, band rupture, band slipping, internal hernia, bowel obstruction, incisional hernia, cholelithiasis and gastric dumping syndrome. Major medical complications included cardiac arrest, acute respiratory distress syndrome, disseminated intravascular coagulation, septicaemia, thrombotic event and intensive care unit (ICU) admission.

Perinatal outcomes were birthweight (grams), low birthweight (<2.5kg), macrosomia (>4kg), SGA infants, large for gestational age (LGA) infants, gestational age at birth (completed weeks), preterm birth (<37 weeks), neonatal unit admission, low Apgar score (<7 at 5 minutes), congenital abnormalities, stillbirth and neonatal death. Birthweight percentiles for gestation (z scores) were calculated using UK-WHO growth reference charts.[21] SGA was defined as birthweight <10th percentile for gestational age and LGA as birthweight >90th percentile for gestational age.

Confounding factors were included in the multivariable model if biologically plausible. Covariates included age, parity, ethnicity, early pregnancy BMI, smoking status, employment status and pre-existing diabetes.

2.4. Statistical methods

Procedure-specific prevalence rates were derived using number of maternities after each type of bariatric surgery in one-year as the nominator and total number of UK maternities (in 2012 for gastric banding and 2015 for gastric bypass and sleeve) recorded in NHS maternity statistics as the denominator.[22]

Frequencies and proportions, or means and medians with respective standard deviations and interquartile ranges are reported, depending on data distribution. The three bariatric groups could not be compared within the same modelling framework since data in the sleeve group was sparse and unbalanced. The following inferential statistics were performed:

2.4.1. Comparisons between maternities after gastric banding and bypass

Univariable and multivariable comparisons of categorical outcomes were performed using modified Poisson regression[23] and results reported as RRs and 95%CIs. GWG and BMI change were compared using linear mixed regression to account for repeated measurements within the same individuals. To account for missing data on third trimester weight and BMI, we used multiple imputation (20 sets using chain equations under missing at random (MAR) assumption)[24] and Rubin’s combination rules.[25] Sensitivity analyses were performed for three scenarios using single value imputation under missing not at random (MNAR) assumption: weights or BMIs equal to the 25th, 50th and 75th percentiles of third trimester observed weights or BMIs for each surgical group were imputed. Birthweights were compared using generalized least square model, and gestational age using quantile regression due to skewed distribution.

2.4.2. Comparisons of maternities after sleeve gastrectomy with gastric banding and bypass

Comparisons were unadjusted due to the small number of maternities in the sleeve group. Categorical outcomes were compared using unconditional Barnard test, which tests the null hypothesis of no difference in proportion between groups. This test is more appropriate than Fisher's exact test when outcomes are rare and unbalanced.[26] Results reported as differences in proportion and 95%CIs. Continuous outcomes were analyzed using the methods described above, including imputation of missing data for GWG and BMI change.

2.4.3. Subgroup analysis within gastric bypass group

Outcomes were compared between maternities after Roux-en-Y gastric bypass and unknown type of bypass. Loop and laparoscopic bypass were uncommon and not analyzed.

Analyses were performed using Stata version 14.2, and R 3.5.1.

2.5. Ethical approval

Data were collected with Research Ethics Committee approvals (gastric band: NRES 11/SW/0227, gastric bypass: NRES 14/LO/0491). UKOSS methodology has Research Ethics Committee approval.[27]

3. Results

UKOSS data collection was complete for 94% of notified women during the collection periods. We collected data for 333 maternities following bariatric surgery (Figure 2).

Between November 2011 and October 2012, there were 127 cases of women pregnant after gastric banding in an estimated 721,574 maternities[22] (UK prevalence: 17.6 per 100,000 maternities (95%CI [14.7-21.0])). Between April 2014 and March 2016, there were 134 cases of pregnancy following gastric bypass (UK prevalence: 9.7 per 100,000 maternities (95%CI [8.2-11.5])) and 29 cases of sleeve gastrectomy (UK prevalence: 2.1 per 100,000 maternities (95%CI [1.4-3.1])) in an estimated 1,377,097 maternities.[22]

Details of participant characteristics for pregnancies after gastric band, bypass and sleeve are presented in Table 2 and for subgroups of gastric bypass in Table S1.

3.1. Maternal outcomes

3.1.1. Gestational weight gain and BMI change (Figure 3 and Table S2)

Booking weight was higher in women pregnant with gastric banding than those with bypass (+8.0kg, 95%CI [2.4-13.5]) and sleeve (+10.9kg, 95%CI [2.9-19.0]). There was evidence of greater gestational weight gain in the gastric banding compared with bypass group when missing data were accounted for with multiple imputation under MAR assumption (+3.6kg, 95%CI [0.24-7.0]). Sensitivity analysis using single imputation under MNAR assumption further strengthened these findings.

Gestational weight gain was comparable between pregnancies after sleeve gastrectomy and gastric banding or bypass when multiple imputation under MAR assumption was used for missing data. However, imputation of observed median and 75th percentile weights suggested evidence of greater weight gain amongst women who had gastric banding compared with sleeve (scenario III (75th percentile): +9.3kg, 95%CI [1.7-16.9]).

3.1.2. *Obstetric and medical outcomes (Tables 3 and S3)*

Risk of anaemia during pregnancy following gastric banding (15.9%) and sleeve (21%) was lower compared to those who had bypass (38.6%) (band vs bypass: adjusted RR=0.44 [0.27-0.72]; sleeve vs bypass: difference in proportion=0.20, [0.01-0.35]).

Risk of gestational diabetes (GDM) was lower after gastric banding (7%) than after bypass (16%) (adjusted RR=0.35 [0.13-0.92]). In the gastric band cohort, 84% of women had GDM screening, compared with 63% in the bypass cohort. Type of screening was variable, with 45% of women with gastric bypass having oral glucose tolerance testing.

Other obstetric and medical outcomes were comparable between bariatric surgery types.

3.1.3. Surgical and major medical complications (Table 3)

Surgical complications were lower in pregnancies after gastric banding (0.9%) compared with bypass (11.4%) (adjusted RR=0.08 [0.008-0.70]). There were no significant differences in major medical complications between different types of surgery.

In the gastric bypass group, surgical complications included: 1 incisional hernia, 2 intussusceptions, 1 bowel obstruction, 3 cases of cholelithiasis and 9 cases of gastric dumping syndrome. One pregnant woman died from surgical complications related to her gastric bypass. Major medical complications included: 1 case of septicaemia, 1 thrombotic event and 4 cases of intensive care unit admission.

In the gastric band group, one woman suffered band slippage necessitating total parenteral nutrition and laparoscopic removal. Major medical complications included: 2 thrombotic events and 1 intensive care unit admission, unrelated to band complications.

3.2. Perinatal outcomes (Tables 4 and S4)

3.2.1. Fetal growth

Infants born to mothers who had gastric banding had a higher birthweight (mean=3380g) than those born to mothers who had bypass (mean=3159g) (mean difference=+260g, [125-395]). Infants born to mothers who had gastric banding were more likely to be large for gestational age (LGA; using z scores) than those who had bypass (adjusted RR=4.74 [1.54-14.6]) or sleeve (difference in proportion=+0.17

[0.02-0.27]). The risk of a small for gestational age (SGA) infant was comparable between groups.

3.2.2. Preterm birth

Infants of mothers who had gastric banding were more likely to be born preterm (13.1%) than those born to mothers who had bypass (8.3%) (adjusted RR=2.27 [1.02-5.03]). Rates of elective preterm birth >34 weeks was similar between groups (banding: 3.7%, bypass: 3.0%). The risk of preterm birth was comparable between women who had sleeve and bypass / banding.

3.2.3. Morbidity and mortality

Risk of neonatal unit admission, low Apgar score, congenital abnormalities, stillbirth and perinatal death were similar between groups.

3.3. Subgroup analysis (Tables S5 and S6)

There was a higher risk of macrosomia in pregnancies following unspecified gastric bypass compared with Roux-en-Y (difference in proportion=-0.07[-0.17 - -0.01]). All other maternal and perinatal outcomes were similar between bypass subgroups.

4. Discussion

Pregnancies after gastric bypass were associated with increased risk of surgical complications and maternal anaemia compared with those after gastric banding or sleeve. Infants born to women who had gastric bypass had a lower birthweight but no increased risk of being SGA compared with infants of mothers who had banding. However, there was a higher risk of LGA infants in the gastric banding compared with bypass and sleeve groups. The risk of preterm birth was also higher in maternities following gastric banding compared with bypass.

4.1. Strengths and limitations

This is the first national prospective study to compare pregnancy outcomes between distinct cohorts of women with different types of bariatric surgery. UKOSS is a well-established surveillance system with comprehensive coverage and high ascertainment. Data were collected prospectively eliminating recall bias. The UKOSS cohorts spanned a total period of four and a half years. As opposed to studies examining pregnancies across different decades (Table 1), comparisons between the UKOSS cohorts are less likely to be affected by temporal changes in healthcare practice. For comparisons between gastric bypass and banding, we performed multivariable analyses adjusting for factors that may influence maternal and perinatal outcomes. However, there may be residual confounding from behaviour and lifestyle factors.

We did not perform power calculations as there was no single primary outcome on which to base one and there is evidence against post-hoc sample size calculation.[28] However, the relatively modest sample size limited our ability to detect differences in rare outcomes and following sleeve gastrectomy. We undertook steps to mitigate the impact of unbalanced and rare events and performed sensitivity analyses to minimise the impact of missing data. We acknowledge that there may be some residual heterogeneity in our comparison groups. For example, women pregnant following gastric banding included those with an inflated and deflated band.[19] Many women in the gastric bypass cohort had unspecified bypass surgery.

However, subgroup analyses revealed no significant differences in important outcomes following Roux-en-Y and unspecified gastric bypass.

4.2. Interpretation

Differences in outcomes between restrictive and malabsorptive procedures may relate to macronutrient deficiencies, for which gestational weight gain can be used as a surrogate marker, and micronutrient deficiencies, for example, anaemia.[29] We found evidence of higher booking BMI and increased gestational weight gain in maternities after gastric banding compared with bypass. In contrast, pregnancies after gastric bypass were associated with a higher risk of anaemia compared to other bariatric procedures. Maternal anaemia is associated with an increased risk of low birthweight infants.[30] Existing evidence for risk of fetal growth restriction in pregnancies following malabsorptive compared with restrictive procedures is variable[15,16,30] In this study, women with gastric bypass had a lower infant birthweight compared to women with banding but we found no evidence of a difference in SGA risk.

Previous studies comparing outcomes with non-surgical controls, have found higher incidences of preterm birth in pregnancies following bariatric surgery[14] and specifically, gastric banding.[31] We identified a higher risk of spontaneous preterm birth in pregnancies after gastric banding compared with bypass. This may be related to the higher rates of residual obesity in the gastric band group, although this should in part be mitigated by adjustment for BMI.

The increased risk of GDM in women pregnant after gastric bypass compared with banding is surprising. It may be due to the type of diabetes screening performed: In women with gastric bypass, the conventional oral glucose tolerance test can trigger gastric dumping syndrome and variable glucose levels following the glucose load[32]. This can impair interpretation of results and lead to unpleasant symptoms and potential harm to mother and baby. Therefore, alternative GDM screening methods are recommended for women pregnant after gastric bypass.[32,33]

This study highlights the increased risk of surgical complications in pregnancies following gastric bypass. Rising intra-abdominal pressure during pregnancy increases the risk of internal hernia[34] and small bowel obstruction.[35] These complications can have devastating consequences including maternal or fetal death.[36] In women of reproductive age, mesenteric defects should be closed at primary bypass surgery to reduce the risk of internal hernia.[37] Obstetricians must also be mindful of potential surgical complications and involve surgeons early in women with gastric bypass presenting with abdominal pain.[38]

5. Conclusion

The increased risk of maternal morbidity related to surgical complications after gastric bypass is concerning. There is currently no consensus regarding the type of bariatric procedure preferable to women planning a future pregnancy. Further studies are needed to establish if restrictive procedures should be used in preference to malabsorptive for women planning to have children[39].

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Conflict of interest

None.

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Tables and figures

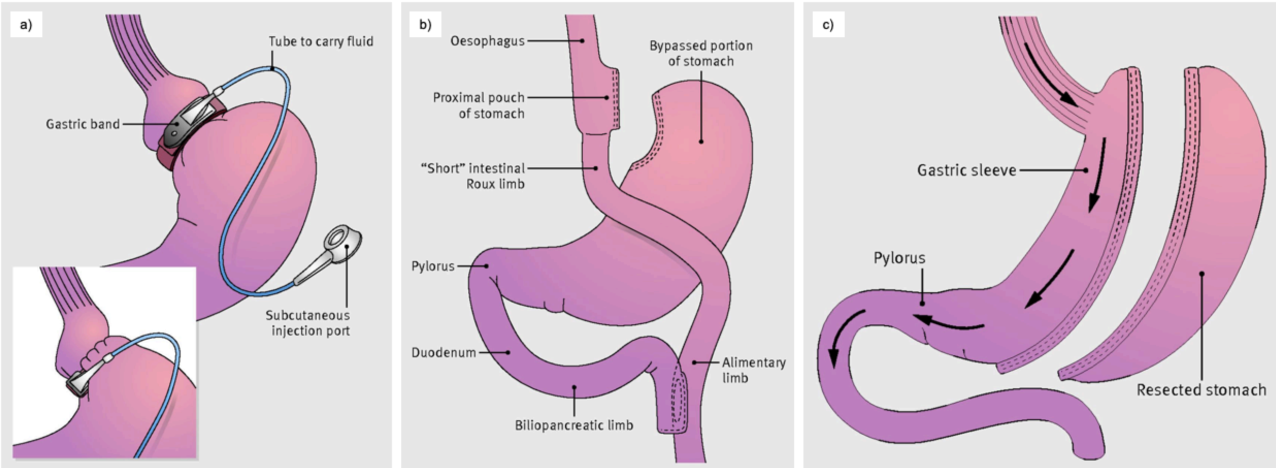

Figure 1 Types of bariatric surgery: a) Gastric banding: an adjustable band is placed around the upper portion of the stomach to create a small upper pouch and a narrow opening into the main body of the stomach. b) Gastric bypass: Food intake is restricted by creating a small pouch at the gastric fundus, whilst the main body of the stomach, duodenum and length of jejunum are bypassed (Roux-en-Y). c) Sleeve gastrectomy: the greater curvature of the stomach is removed, resulting in a narrow gastric sleeve. Reproduced from : 'What is the most effective operation for adults with severe and complex obesity' J Blazeby, J Byrne, R Welbourn; 348; 4-5;2014 with permission from BMJ Publishing Group Ltd

able 1 Summary of key studies comparing pregnancy outcomes following different types of bariatric surgery published in the last decade

Study	Study design	Period of observation	No. cases	Comparison[a]	Types of Surgery	Distinct or conflated comparisons[b]
This study	Cohort[c]	5 years	290	Bypass vs banding vs sleeve	Bypass / Banding / Sleeve	Distinct
Shai et al 2013	Case-control	22 years[d]	326	Different obese women without BS	Bariatric surgery (undifferentiated)	Conflated
Aricha-Tamir et al 2012	Case-control	20 years[d]	144	Same women before BS	Bypass / Banding / Gastroplasty	Conflated
Grandfils et al 2019	Cohort	14 years[d]	337	Insufficient vs adapted vs excessive gestational weight gain	Bypass / Banding / Sleeve	Conflated
Lapolla et al 2010	Cohort	12 years[e]	83	A. Different obese women without BS B. Same women before BS	Banding	Conflated
Josefsson et al 2011	Cohort	10 years[f]	681	A. Different women without BS B. Same women before BS	Bypass / Banding / Gastroplasty	Conflated
Kjaer et al 2013	Case-control	6 years[d]	339	Different women without BS (BMI matched)	Bypass / Banding	Conflated
Amsalem et al 2014	Case-control	6 years[d]	109	Same women before BS	Banding / Gastroplasty	Conflated
Johansson et al 2015	Case-control	5 years[d]	670	Different women without BS (BMI matched)	Bypass / Banding / Other	Conflated
Bennett et al 2010	Cohort	4 years[g]	585	Same women before BS	Bypass / Banding / Other	Conflated
Burke et al 2010	Cohort	4 years[e]	354	Different obese women without BS	Bypass / Banding	Conflated
Lesko et al 2012	Case-control	4 years[d]	70	Different women without BS (BMI matched)	Bypass / Banding	Conflated
Belogolovkin et al 2012	Cohort	3 years[d]	293	Different obese women without BS	Bariatric surgery (undifferentiated)	Conflated
Balestrin et al 2019	Case-control	2 years[d]	93	Different obese women without BS	Bypass / Restrictive procedures	Conflated
Parker et al 2015	Cohort	1 year[d]	1585	Different obese women without BS	Bariatric surgery (undifferentiated)	Conflated
Sheiner et al 2009	Cohort	20 years[e]	449	Between different surgery types A. Bypass vs banding vs gastroplasty B. Malabsorptive vs restrictive	Bypass / Banding / Gastroplasty	Distinct
Roos et al 2013	Case-control	17 years[d]	2,562	A. Different women without BS (BMI matched) B. Between subgroups of different surgery types	Bypass / Banding / Gastroplasty	Distinct
Berlac et al 2014	Cohort	15 years[e]	415	Different women without BS (BMI matched)	Bypass	Distinct
Gonzalez et al 2014	Cohort	14 years[d]	168	Restrictive vs malabsorptive	Bypass / Banding / Sleeve / Gastroplasty / Biliopancreatic diversion	Grouped according to malabsorptive vs restrictive
Coupaye et al 2018	Cohort	13 years[d]	123	Bypass vs sleeve	Bypass / Sleeve	Distinct
Chevrot et al 2016	Case-control	9 years[e]	139	A. Different women without BS (BMI matched) B. Malabsorptive vs restrictive	Bypass / Banding / Sleeve	Grouped according to malabsorptive vs restrictive
Watanabe et al 2019	Case-control	9 years[e]	24	Bypass vs banding vs sleeve	Bypass / Banding / Sleeve	Distinct
Santulli et al 2010	Cohort	6 years[d]	24	Different women without BS (BMI matched)	Bypass	Distinct
Ducarme et al 2012	Cohort	5 years[d]	94	Bypass vs banding	Bypass / Banding	Distinct
Facchiano et al 2012	Cohort	4 years[d]	42	Bypass vs banding	Bypass / Banding	Distinct
Hammeken et al 2017	Cohort	3 years[d]	151	Different women without BS (BMI matched)	Bypass	Distinct
Jefferys et al 2016	Cohort	1 year[d]	127	Inflated vs deflated gastric band	Banding	Distinct

[a]BS = Bariatric surgery, [b]Pregnancy outcomes analyzed with different types of procedure grouped together (conflated) or by procedure type (distinct). [c]Prospective study. All other studies retrospective. [d]During which births occurred, [e]During which surgeries performed, [f]During which women born, [g]During which claims made

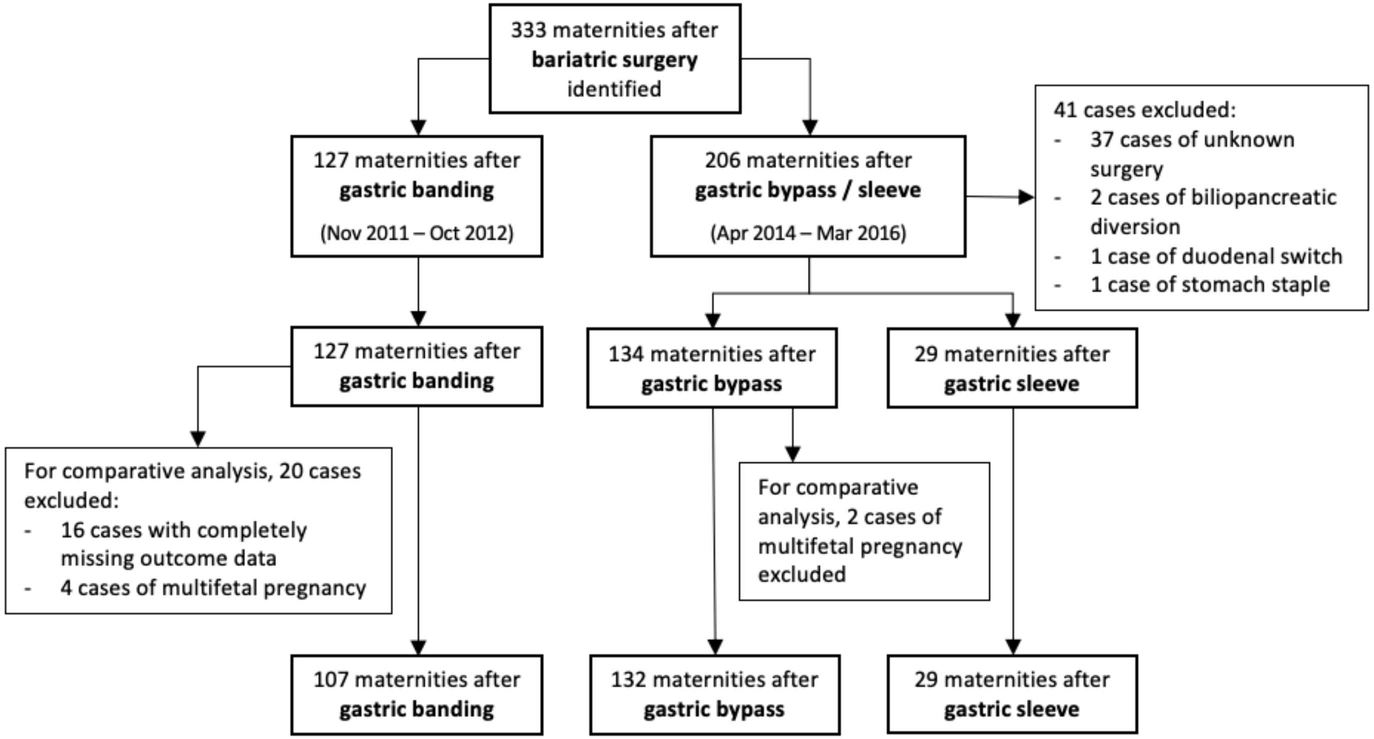

Figure 2 Flowchart of the gastric banding and bypass / sleeve cohorts

Table 2 Participant characteristics

		Overall (n=268)	Type of surgery		
			Gastric Banding (n= 107, 40%)	Gastric Bypass (n=132, 49%)	Sleeve Gastrectomy (n=29,11%)
Maternal age (years)	Mean (SD)	32.9(5.2)	31.8 (4.9)	33.5(5.2)	34.2 (5.8)
	Missing (n)	0	0	0	0
BMI at booking	Mean (SD)	34.5 (7.0)	36.4 (7.3)	33.6 (6.8)	32.0 (5.3)
	Missing (n)	2	1	0	1
Weight at booking (kg)	Mean (SD)	96 (20.1)	101.6 (20.9)	92.5 (19.7)	90.2 (15)
	Missing (n)	2	1	0	1
Parity[a] n (%)	Nulliparous	99	50 (47)	37 (28)	12 (41)
	Parous	166	57 (53)	92 (70)	17 (59)
	Grandparous	3	0 (0)	3 (2)	0 (0)
	Missing (n)	0	0	0	0
Ethnicity n (%)	White	246	100 (93)	122 (92)	24 (83)
	Asian	11	4 (4)	6 (5)	1 (3)
	Black African	3	1 (1)	2 (2)	0 (0)
	Mixed, other	8	2 (2)	2 (2)	4 (14)
	Missing (n)	0	0	0	0
Employment n (%)	Employed	178	78 (73)	84 (64)	16 (55)
	Unemployed	82	26 (24)	44 (33)	12 (41)
	Missing (n)	8	3	4	1
Smoking during pregnancy n (%)	Yes	38	15 (14)	18 (14)	5 (17)
	No	227	92 (86)	112 (85)	23 (79)
	Missing (n)	3	0	2	1
Pre-existing Diabetes n (%)	Yes	33	7 (7)	20 (15)	6 (21)
	No	235	100 (93)	112 (85)	23 (79)
	Missing (n)	0	0	0	0
Pre-existing hypertension n (%)	Yes	26	11 (10)	12 (9)	3 (10)
	No	242	96 (90)	120 (91)	26 (90)
	Missing (n)	0	0	0	0

[a]Nulliparous = 0 previous maternities; Parous = 1-4 previous maternities; Grandparous = 5-8 previous maternities
Inferential measures and significance tests not performed, as per STROBE guidelines

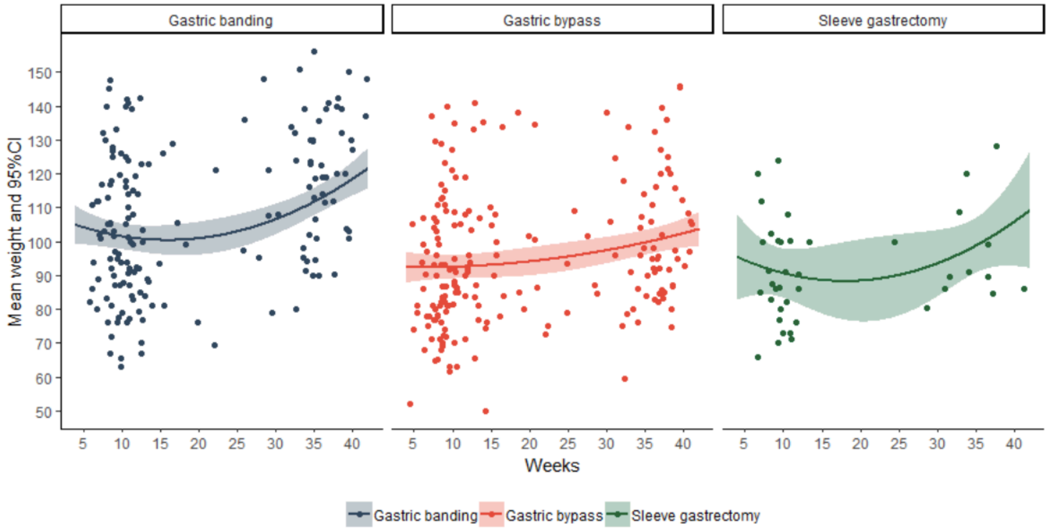

Figure 3 Weight change during pregnancies after gastric band, bypass and sleeve

Table 3 Comparison of maternal outcomes between pregnancies after gastric banding, bypass and sleeve

		Gastric banding (n=107)	Gastric bypass (n=132)	Sleeve gastrectomy (n=29)	Banding vs Bypass				Banding vs Sleeve		Bypass vs Sleeve	
					Unadjusted analyses		Adjusted analyses[a]		Difference in proportion (95%CI)[b]	p value	Difference in proportion (95%CI)[b]	p value
					RR (95%CI)	p value	RR (95%CI)	p value				
Pre-eclampsia (n, %)	Yes	3 (2.8)	4 (3.0)	0 (0)	0.90 (0.21,3.94)	0.91	1.39 (0.48,4.00)	0.54	0.03 (-0.10,0.08)	0.47	0.03 (-0.10,0.07)	0.43
	No	99 (92.5)	119 (90.2)	29 (100)								
	Missing	5 (4.7)	9 (6.8)	0 (0)								
Gestational Diabetes[c] (n, %)	Yes	7 (7)	18 (16)	1 (4)	0.42 (0.18,0.96)	0.03	0.35 (0.13,0.92)	0.03	0.03 (-0.15,0.11)	0.82	0.14 (-0.06,0.24)	0.09
	No	90 (90)	87 (78)	22 (96)								
	Missing	3 (3)	7 (6)	0 (0)								
Anaemia (n, %)	Yes	17 (15.9)	51 (38.6)	6 (21)	0.40 (0.25,0.65)	<0.001	0.44 (0.27,0.72)	0.002	-0.03 (-0.21,0.11)	0.74	0.20 (0.01,0.35)	0.04
	No	85 (79.4)	72 (54.5)	23 (79)								
	Missing	5 (4.7)	9 (6.8)	0 (0)								
Surgical complications (n, %)	Yes	1 (0.9)	15 (11.4)	0 (0)	0.08 (0.01,0.60)	0.001	0.08 (0.008,0.70)	0.03	0.009 (-0.12,0.05)	0.73	0.11 (-0.03,0.18)	0.06
	No	101 (94.4)	108(81.8)	29 (100)								
	Missing	5 (4.7)	9 (6.8)	0 (0)								
Major medical complications (n, %)	Yes	3 (2.8)	5 (3.8)	0 (0)	0.61 (0.16,2.40)	0.73	0.63 (0.10,3.71)	0.60	0.03 (-0.10,0.08)	0.46	0.04 (-0.07,0.10)	0.28
	No	99 (92.5)	118 (89.4)	29 (100)								
	Missing	5 (4.7)	9 (6.8)	0 (0)								

Cases with missing observations (outcome or covariates) removed prior to analysis.
[a]Adjusted analyses using Poisson regression model.
[b]Unadjusted analyses using Barnard exact test. Adjustment not possible due to sparse and unbalanced data.
[c]Cases with pre-existing diabetes excluded.

Table 4 Comparison of perinatal outcomes between pregnancies after gastric banding, bypass and sleeve

		Gastric banding (n=107)	**Gastric bypass** (n=132)	**Sleeve gastrectomy** (n=29)	**Banding vs Bypass**				**Banding vs Sleeve**		**Bypass vs Sleeve**	
					Unadjusted analyses		Adjusted analyses		Mean difference / Difference in proportion (95%CI)[b,c]	p value	Mean difference / Difference in proportion (95%CI)[b,c]	p value
					Mean difference / RR (95%CI)[a]	p value	Mean difference / RR (95%CI)[a]	p value				
Birth weight (g)[d]	Mean	3380	3159	3199	221 (64,380)	0.006	260 (125,395)	<0.001	138 (-97,373)	0.25	-90 (-320,140)	0.44
	SD	641	530	487								
	Missing	7 (6.5)	10 (7.6)	3 (10)								
Small for gestational age[e] (n, %)	Yes	7 (7)	14 (11)	1 (3)	0.66 (0.27,1.58)	0.48	0.46 (0.16,1.33)	0.15	0.03 (-0.11,0.11)	0.60	0.07 (-0.07,0.15)	0.26
	No	98 (92)	117 (89)	28 (97)								
	Missing	2 (2)	1 (0)	1 (0)								
Large for gestational age[e] (n, %)	Yes	22 (21)	6 (5)	1 (3)	4.27 (1.79,10.17)	<0.001	4.74 (1.54,14.6)	0.006	0.17 (0.02,0.27)	0.03	0.01 (-0.14,0.07)	0.89
	No	83 (78)	125 (95)	28 (97)								
	Missing	2 (2)	1 (0)	1 (0)								
Preterm birth[e] (n, %)	Yes	14 (13)	12 (9)	4 (14)	1.54 (0.73,3.24)	0.29	2.27 (1.02,5.03)	0.04	-0.006 (-0.18,0.11)	0.98	-0.05 (-0.22,0.06)	0.50
	No	92 (86)	119 (90)	25 (86)								
	Missing	1 (1)	1 (1)	0 (0)								
Stillbirth[e] (n, %)	Yes	1 (0.9)	1 (0.8)	0 (0)	-		-		-		-	
	No	104 (97.2)	131 (99.2)	29 (100)								
	Missing	2 (0)	0 (0)	0 (0)								

Cases with missing observations (outcome or covariates) removed prior to analysis
[a]Mean difference reported for continuous outcome (birth weight) and RR reported for categorical outcomes
[b]Mean difference reported for continuous outcome (birth weight) and difference in proportion reported for categorical outcomes.
[c]Unadjusted analyses using Barnard exact test. Adjustment not possible due to sparse and unbalanced data.
[d]Adjusted analyses for banding vs bypass comparison using generalised least square model
[e]Adjusted analyses for banding vs bypass comparison using Poisson regression model

Supplementary tables and figure legends

Table S1 Participant characteristics for subgroups of bypass cases

Table S2 Analysis of weight gain and BMI change including missing data imputation

Table S3 Comparison of all maternal outcomes after gastric band, bypass and sleeve

Table S4 Comparison of all perinatal outcomes after gastric band, bypass and sleeve

Table S5 Subgroup analysis of maternal outcomes according to type of bypass surgery

Table S6 Subgroup analysis of perinatal outcomes according to type of bypass surgery