

Impact of Bariatric Surgery on Pregnancy: A Systematic Review and Meta-analysis

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Abstract

Introduction:

Bariatric surgery (BS) is an increasingly common intervention for women of reproductive age with morbid obesity, however the optimal timing of pregnancy following surgery has not yet been fully established, particularly as it impacts both obstetric and neonatal outcomes.

Methods:

Systematic search of Medline, EMBASE, EMCARE, and Cochrane databases identified 2468 studies for screening; 129 met inclusion criteria. The meta-analysis included women who underwent various BS procedures followed by pregnancy. Outcomes were analyzed using a random-effects model, comparing early (<12 months) and later (>12 months) post-surgery conception. Maternal outcomes included gestational weight gain (GWG), gestational diabetes (GDM), pre-eclampsia, preterm birth, caesarean delivery, induction of labour, postpartum hemorrhage (PPH), anaemia, and internal hernia. Neonatal outcomes included Apgar scores, birthweight, gestational age, Neonatal intensive care unit (NICU) admissions, macrosomia, intrauterine growth restriction (IUGR), and perinatal death.

Results: Bariatric surgery reduced pre-pregnancy BMI by 14 kg/m² (95% CI: 13–15 kg/m², I² = 93.1%, p=0.000). Postoperative pregnancies had lower odds of gestational diabetes (OR 0.67, 95% CI: 0.53–0.85), pre-eclampsia (OR 0.60, 95% CI: 0.45–0.79), and macrosomia (OR 0.35, 95% CI: 0.24–0.50), but higher odds of intrauterine growth restriction (OR 2.09, 95% CI: 1.92–2.27), prematurity (OR 1.24, 95% CI: 1.04–1.47) and NICU admission (OR 1.39, 95% CI: 1.17–1.65). Mean GWG in women who conceived within 12 months of BS was 5.2 kg (95% CI: 2.0, 8.0), compared to 10.2 (95% CI: 9.5, 11.1) in women who conceived >12 months after BS. PPH and caesarean rates were similar between post-BS pregnancies and obese controls. The prevalence rate of anaemia was 26% (95% CI: 22–31) and Vitamin D deficiency was 69.0% (95% CI: 61.8, 76.2).

Conclusion:

Bariatric surgery reduces obstetric risks of GDM, hypertensive disorders, and macrosomia. However, conception within 12 months is associated with lower GWG. BS increased odds of IUGR and preterm birth without significant difference in peri-natal mortality. Nutritional deficiencies, including anaemia, and fat-soluble vitamins, require close monitoring, particularly in early post-surgical pregnancies.

Background

Maternal obesity, defined as a pre-pregnancy body mass index (BMI) of ≥ 30 kg/m², presents significant risks for both mother and foetus (1, 2). Despite growing awareness, maternal obesity has reached epidemic proportions, with prevalence rates of 31.9% in the United States, 21.3% in the United Kingdom, and similar increasing trends across Europe (2–4).

During pregnancy, physiological insulin resistance increases due to placental secretion of diabetogenic hormones, including growth hormone, corticotropin-releasing hormone, placental lactogen, and prolactin,

predisposing women to gestational diabetes mellitus (GDM) (5, 6). Obese women experience a more pronounced decline in insulin sensitivity than those with normal weight, leading to an elevated risk of GDM and associated complications such as preeclampsia, gestational hypertension, fetal macrosomia, and higher rates of caesarean delivery (7). Additionally, maternal obesity has been linked to an increased likelihood of miscarriage, congenital anomalies due to hyperglycaemia during early organogenesis, and a heightened risk of venous thromboembolism (8, 9). Given these adverse outcomes, clinical guidelines from the American College of Obstetricians and Gynecologists and the Institute of Medicine (IOM) recommend BMI assessments at the first antenatal visit, with specific gestational weight gain targets of 5–9 kg for women with obesity (7, 10)

Bariatric surgery (BS) is the most effective long-term intervention for obesity, with over half of procedures performed on women of reproductive age (11, 12). A range of bariatric procedures are commonly performed including gastric banding, laparoscopic sleeve gastrectomy (LSG) and Roux-en-Y gastric bypass (RYGB). Mechanisms of weight loss are multifactorial and are not simply due to reduced food intake but rather a reset of the gastro-hormonal milieu, which ultimately increases satiety hormones, reduces hunger hormones and improves insulin sensitivity, a detailed discussion of which is beyond the scope of this paper (13). Post-operative weight loss and the associated metabolic adaptations have been associated with significant improvements in fertility and reduction in co-morbidities, including diabetes, hypertensive disorders, Asthma, etc. (11,14,15). However, women should be thoroughly counselled on the risks of early conception during this rapid weight loss phase, as malnutrition following BS can lead to insufficient gestational weight gain (GWG), small-for-gestational-age (SGA) neonates, and preterm birth (16, 17). Maternal deficiencies in essential micronutrients such as folate, iron, vitamin B12 and fat-soluble vitamins have been linked to adverse perinatal outcomes, including neural tube defects, low birth weight, and preterm delivery (18). Conversely, some women may have insufficient weight loss (IWL) with impaired efficacy of the BS intervention, particularly if pregnancy occurs before weight stabilization. While data suggest that fertility outcomes improve and the overall maternal and neonatal risks remain acceptable following BS, maintaining adequate maternal nutrition and vitamin supplementation remains critical to optimising pregnancy outcomes (19–21).

Current consensus is to advise women to delay conception until achieving a stable weight following BS, typically beyond a minimum of 12 months, to reduce the risks of adverse pregnancy outcomes and above-mentioned nutritional deficiencies (22–25). However, in cases of advanced maternal age or diminished ovarian reserve, earlier conception may be considered, balancing potential benefits against residual obesity-related risks (22). A dichotomous cut-off of 12 months does not adequately reflect the complexity of post-surgical changes and a more nuanced approach to individual variation is key.

Objectives: This systematic review and meta-analysis aims to provide an up-to-date evaluation of the impacts of BS on pregnancy outcomes while also examining the evidence regarding pregnancy timing after surgery. Understanding these variables is essential for optimising maternal and neonatal health, guiding clinical recommendations, and informing future research on long-term outcomes.

MATERIALS AND METHODS

This systematic review was conducted according to a registered protocol and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The review was registered on PROSPERO Centre for Reviews and Dissemination (registration number: CRD42025622448).

Literature search

A comprehensive search was performed in electronic databases including Pubmed/Medline, EMBASE/OVID and the Cochrane library and they were reviewed from 2014 up to November 2024. The literature search included the following MeSH terms used in all possible combinations: "sleeve gastrectomy", "gastric sleeve", "LSG", "laparoscopic sleeve gastrectomy", "bariatric sleeve surgery", "roux-en-y gastric bypass", "gastric bypass", "RYGB", "revisional surgery", "conversion surgery", "repeat surgery", "sleeve to bypass", "sleeve gastrectomy to gastric bypass". Studies identified from the search strategy were entered into Covidence (Victoria, Australia) for bibliographic management and duplicates were removed. Two authors, KW and MF independently identified relevant studies, and any discrepancies were resolved by a third reviewed (SB). The exact search strategy has been provided as supplementary material (Sup. 1).

Eligibility criteria

The inclusion and exclusion criteria were defined before the commencement of the literature search. The included studies provided clinical data and outcome rates on women of childbearing age who had undergone bariatric surgery for weight loss with subsequent pregnancy. Bariatric surgery referred to Laparoscopic sleeve gastrectomy (LSG), Roux-en-y gastric bypass (RYGB) or One-anastomosis gastric bypass (OAGB). Eligible study designs included randomised controlled trials (RCT), prospective or retrospective cohort studies, case (control) studies, cross-sectional studies and reviews. Both single-arm and double-arm comparative studies were included. Non-human studies, abstracts, conference presentations, single case reports, editorials and unpublished studies were excluded from the analysis.

Quality assessment

The quality of studies was assessed using the revised Cochrane's risk of bias tool (RoB2) for RCTs and the Newcastle-Ottawa scale for observational studies without randomisation (26, 27)

Data extraction and handling

A standardised data extraction form was developed on Covidence and the authors AR, CN and JHY independently extracted all relevant data from full text study documents including: study design, sample

size, type of bariatric surgery, mean/median maternal BMI (Body mass index), mean incidence of GDM; gestational hypertension, Pre-eclampsia, Pre-term labour, post-partum haemorrhage, anaemia and internal hernia (including SD). Mean APGAR scores, birthweight, gestational age, Neonatal ICU admission rates, Macrosomia, Intra-uterine growth restriction and peri-natal deaths were extracted. Any discrepancy was resolved by an independent reviewer (MF).

Statistical Analysis

Statistical analysis was performed using Stata Software (StataCorp LCC, TX, Version 15.1.) and RevMan (RevMan, Copenhagen: The Nordic Cochrane Centre, the Cochrane Collaboration, 2008). Random effects analysis was used to calculate pooled prevalence estimates for all studies across all outcomes. All studies were included in the meta-analysis if relevant data was available. When studies reported multiple bariatric subgroups, they were separated into distinct categories (e.g., A, B, C) and included as independent entries in the pooled analysis. For studies reporting data for both bariatric and control groups, study effect sizes were combined using odds ratios (OR) along with corresponding 95% confidence intervals (95% CI:) under the random-effects meta-analysis model (inverse variance method). For all results, the DerSimonian and Laird method was applied to account for between-study heterogeneity (I^2). We considered an I^2 of 30 or less as low, between 30 and 60 to be moderate, and 60 or over as high heterogeneity.

Definition of outcomes

The primary outcomes of interest were divided into maternal and neonatal. Maternal outcomes included: Gestational diabetes, gestational hypertension, pre-eclampsia, pre-term labour, C-section, induction of labour, postpartum haemorrhage, anaemia and internal hernia. Neonatal outcomes included: Apgar scores, birthweight, gestational age, NICU admission rates, macrosomia, intra-uterine growth restriction and perinatal death. Regarding timing of surgery: 'Early' refers to a bariatric surgery conception interval (BSCI) less than 12 months, and 'Late' refers to BSCI greater than 12 months.

RESULTS

Study Selection

The search identified 2468 relevant citations. After removing duplicates, 1809 articles were screened for titles and abstracts, and 231 studies were included for full-text review. Following final screening, 129 studies met the inclusion criteria for quantitative synthesis (Fig. 1).

Study Characteristics

Of the 129 studies, 110 were retrospective (85.2%) and 19 were prospective (14.7%). Seventeen were multicentre studies and eight were national, with sample sizes ranging from 5 to 66,380 patients. The overall methodological quality of observational studies, assessed using the Newcastle–Ottawa Scale, was high (80.2%). Poor-quality studies were excluded (Suppl. 2). Among included participants, 45,970

patients (20.2%) had the bariatric procedure type specified, while 181,822 (79.8%) did not differentiate between LSG, RYGB, or OAGB.

Patient Characteristics

Mean maternal age ranged from 27.4 years to 38.1 years and the time of conception post bariatric surgery ranged from 1.4 to 92.4 months (IQR 20.3 to 39.9 months).

Maternal Outcomes

Time to conception

Ninety-three studies reported the interval between surgery and conception, representing 10,644 patients. The pooled mean interval was 29 months (95% CI 27–32). The weighted mean time from RYGB to conception (1541 patients) was 29.5 months (95% CI 25.1–34.0), and from LSG (950 patients) was 24.3 months (95% CI 19.1–29.5).

Pre-pregnancy weight loss

Thirty-four studies, including 6845 patients, reported BMI before bariatric surgery and at conception. The pooled random-effects analysis demonstrated a mean BMI reduction of 14 kg/m² (95% CI 13–15) from pre-surgery to pre-pregnancy.

Gestational weight gain

Gestational weight gain (GWG) was reported in 76 studies involving 11,954 patients with prior bariatric surgery. The random-effects model estimated a pooled mean GWG of 9.66 kg (95% CI 8.53–10.79).

Across 21 comparative studies, women with prior bariatric surgery gained less weight during pregnancy compared to obese controls (mean difference – 1.17 kg, 95% CI – 2.75 to – 0.40).

In procedure-specific analyses, the random-effects weighted mean GWG was 9.33 kg (95% CI 7.79–10.86) after RYGB (17 studies) and 10.12 kg (95% CI 8.25–11.99) after LSG (17 studies).

Gestational diabetes (GDM)

The prevalence of GDM following bariatric surgery was 11% (95% CI 10–12) based on 82 studies including 177,926 patients. Across 39 comparative studies, bariatric surgery was associated with a significantly lower risk of GDM compared with obese controls (pooled OR 0.67, 95% CI 0.53–0.85).

In 60 studies (21,755 patients) comparing conception intervals, the prevalence of GDM was 8% (95% CI 6–10) for BSCI < 12 months and 8% (95% CI 7–10) for BSCI > 12 months. Comparative analysis across 13 studies found no significant difference between early and late conception groups (OR 0.83, 95% CI 0.57–1.20).

Pre-eclampsia

Fifty-four studies, including 171,635 patients, reported on pre-eclampsia, with a pooled prevalence of 5% (95% CI 4–8). In 27 comparative studies, the odds of pre-eclampsia were significantly lower among women with prior bariatric surgery than among obese controls (OR 0.60, 95% CI 0.45–0.79).

Mode of delivery – Caesarean section and Induction of labour

Ninety-five studies including 182,038 patients reported caesarean section rates after bariatric surgery, with a pooled prevalence of 38.6% (95% CI 36.9–40.3). Across 41 comparative studies, women with prior bariatric surgery had higher odds of caesarean delivery than obese controls (OR 1.24, 95% CI 1.01–1.52).

Induction of labour was required in 28% of pregnancies after bariatric surgery (95% CI 22–34), based on 13 studies including 12,820 patients. In 12 comparative studies, women with prior bariatric surgery had higher odds of labour induction (OR 1.34, 95% CI 1.08–1.66).

Postpartum haemorrhage

Fifteen studies (18,615 patients) reported a pooled postpartum haemorrhage rate of 4% (95% CI 4–5). Sixteen comparative studies showed no significant difference between bariatric and control groups (pooled OR 1.17, 95% CI 0.64–2.23).

Internal hernia

Eleven studies including 4578 patients were included in the pooled analysis. The rate of internal herniation after RYGB was 2% (95% CI 1–4). Eight studies (3680 patients) reported diagnostic laparoscopy rates of 3% (95% CI 1–5).

Anaemia and Vitamin deficiencies

Nineteen studies including 4685 patients found a 26% prevalence (95% CI 22–31) of clinically relevant anaemia after bariatric surgery. Thirty-four studies (872 patients) reported micronutrient deficiencies as follows: zinc 19% (95% CI 11–27), vitamin A 61% (95% CI 54–68), vitamin B12 30% (95% CI 21–39), iron 33% (95% CI 27–39), calcium 16% (95% CI 8–23), and vitamin D 69% (95% CI 62–76). Vitamin A and D deficiencies were the most prevalent, whereas calcium and zinc deficiencies showed wider variation due to smaller sample sizes.

Neonatal outcomes

Birthweight

Ninety studies, encompassing 14,204 neonates, reported birthweight. The weighted mean birthweight was 3092 g (95% CI 3056–3129) after RYGB (3107 neonates) and 3038 g (95% CI 3009–3068) after LSG (950 neonates). In 29 comparative studies, neonates born to women with prior bariatric surgery had a significantly lower mean birthweight than controls (mean difference – 205 g, 95% CI – 225 to – 186).

Gestational age

Thirty-two studies reported mean gestational age after RYGB, which included 2746 newborns as 270 days (95% CI: 268–271). Eleven studies, including 1095 neonates reported mean gestational age after LSG as 269 days (95% CI: 267–271). There was insufficient data available to perform a stratified analysis of GA for neonates born to mothers with a BSCI < 12 months versus > 12 months.

Intra-uterine growth restriction

A total of 27 studies involving 72,343 patients reported on intra-uterine growth restriction following bariatric surgery. The pooled effect size was 0.06 (95% CI: 0.05 to 0.07), indicating a low prevalence of 6% for this outcome within the post-surgical population. In the comparative analysis of 13 studies, women with prior bariatric surgery had significantly higher odds of intra-uterine growth restriction compared to controls (OR 2.09, 95% CI: 1.92 to 2.27).

Macrosomia

A total of 31 studies comprising 17,979 patients reported on macrosomia following bariatric surgery. The pooled effect size was 0.05 (95% CI: 0.04 to 0.07), indicating a low occurrence of macrosomia in this population. However, substantial heterogeneity was observed ($I^2 = 87.7\%$).

In a pooled analysis of 19 studies, women with a history of bariatric surgery had significantly lower odds of delivering a macrosomic neonate compared to controls (OR 0.35, 95% CI: 0.24 to 0.50). Heterogeneity was considerable ($I^2 = 87\%$).

There was insufficient data to perform a stratified analysis according to timing of pregnancy after surgery.

Pre-term Birth

A total of 125 studies, including 121,994 patients, reported on preterm birth among women with prior bariatric surgery. The pooled effect size was 0.10 (95% CI: 0.03–0.11), corresponding to a prevalence of 10%. Heterogeneity was high ($I^2 = 85.2\%$).

In the comparative analysis of 33 studies, women with a history of bariatric surgery had higher odds of preterm birth compared to controls (OR 1.24, 95% CI: 1.04–1.47). Heterogeneity across studies was considerable ($I^2 = 95\%$), indicating substantial variability in the reported effect estimates.

Low APGAR scores (< 7) at 5 minutes

Among 10,847 neonates born to mothers with bariatric surgery, the prevalence of low 5-minute APGAR scores was 1.7% (95% CI 1.2–2.2). Thirteen comparative studies showed higher odds of a low APGAR score in the bariatric group (OR 1.38, 95% CI 1.07–1.79).

Admission to Neonatal Intensive Care Unit (NICU)

Seventy-four studies (11,936 neonates) reported a NICU admission rate of 12% (95% CI 10–14).

In 24 comparative studies, neonates of mothers with prior bariatric surgery had higher odds of NICU admission than those of controls (OR 1.39, 95% CI 1.17–1.65). There was insufficient data to perform a stratified analysis according to timing of pregnancy after surgery.

Perinatal deaths

Twelve studies including 66,553 patients reported a pooled perinatal mortality rate of 2% (95% CI 1–2).

Comparative analysis indicated no statistically significant difference in perinatal mortality between groups (OR 1.36, 95% CI 1.00–1.85).

Other complications

Analysis of other significant complications (defined as Clavien-Dindo severity greater than or equal to 3) was pooled from 15 studies including 14727 patients (28). Complications with a severity of Clavien-Dindo 3 or higher i.e. those requiring surgical, endoscopic or radiological intervention, intensive care admission or mortality were reported in 5% (95%CI: 4%-7%).

Table 1. to be placed here

Subgroup Analysis – Early (< 12 months) vs Late (> 12 months) pregnancy post-op

Gestational Weight Gain

In the early conception group (BSCI < 12 months; 483 patients), the weighted mean GWG was 5.24 kg (95% CI 2.04–8.04). In the late conception group (BSCI > 12 months; 3859 patients), it was 10.2 kg (95% CI 9.47–11.11). Across 15 studies, late conception was associated with significantly greater GWG (mean difference 5.07 kg, 95% CI 2.53–7.60).

Pre-term Birth

In pooled subgroup analysis, the risk of preterm birth was 12% (95% CI 7–16) in the early pregnancy group and 11% (95% CI 9–13) in the late group. Comparative analysis of 13 studies found no significant difference between groups (OR 0.88, 95% CI 0.61–1.27).

Figure 1. to be placed here

DISCUSSION

Main findings:

This systematic review and meta-analysis revealed reduced odds of developing GDM, pre-eclampsia and fetal macrosomia in pregnancies after BS compared to women with obesity. Conversely, BS was found to be associated with greater odds of undergoing C-section delivery or induction of labour with no significant impact on the odds of post-partum haemorrhage. Conversely, neonates born to women who have undergone BS have higher odds of IUGR, admission to NICU care and Apgars < 7 at 5 minutes but with no significant difference in peri-natal mortality.

Maternal Outcomes

Our findings confirm that BS is an effective intervention for pre-pregnancy weight loss and significantly reduces average pre-pregnancy BMI. This supports published meta-analyses, which found the reduction in pre-pregnancy BMI (averaging 13.93kg/m²) does not significantly change during early pregnancy and pre-delivery, indicating that weight management is likely to remain stable during pregnancy after initial post-surgery weight loss (40).

Gestational weight gain

Gestational weight gain (GWG) remains a complex issue and is critical for a number of important clinical outcomes, including fetal growth and wellbeing, delivery method, and the risk of weight regain or recurrence of obesity-related co-morbidities. The existing literature links excessive GWG with increased risk of macrosomia, large-for-gestational-age (LGA) infants, caesarean delivery, and GDM, while insufficient GWG correlates with higher risks of IUGR, small-for-gestational-age (SGA) infants, preterm birth, and NICU admissions (16–18, 22–25). Our meta-analysis supports these associations. The prevalence of IUGR was 3% higher in women post-BS compared to women with obesity, whereas macrosomia was 7% less frequent, indicating a trade-off in fetal growth outcomes that requires tailored antenatal monitoring.

The Institute of Medicine (IOM) provides guidelines based on pre-pregnancy BMI, recommending weight gain of 11.5–16 kg for women with a normal BMI (18.5–24.9), 6.8–11.3 kg for those who are overweight (BMI 25–29.9), and 5–9.1 kg for women with obesity (BMI ≥ 30) (29). Our findings suggest women who have undergone BS and reduced pre-pregnancy BMI to < 30kg/m² tend to achieve these targets. Critics of the current IOM guidelines have argued that the weight gain targets are too high, particularly as they do not address concerns regarding post-partum weight retention. Additionally, they do not differentiate between degrees of obesity (Class I to III), which is relevant in the post-bariatric cohort, given that our study found women post-BS have reduced their pre-pregnancy BMI by an average of 14 kg/m² but may still fall within the broad class of obesity (BMI > 30) (28). Furthermore, subgroup analysis demonstrated significantly greater GWG in the late conception group compared to the early conception group (mean difference 5.07 kg), but without significant differences in the odds of GDM or prematurity between subgroups. This finding highlights that maternal weight gain is not the only factor contributing to these observed associations.

For patients and clinicians, comparing GWG between procedures, our meta-analysis found that women who had undergone RYGB gained slightly less weight during pregnancy (9.33kg) compared to LSG (10.12kg), however with overlapping confidence intervals and high heterogeneity, this difference may not be clinically significant. Previous individual studies reported no difference in GWG between RYGB and SG (3)

Overall, our findings underscore that sufficient GWG is necessary for fetal growth, but both inadequate and excessive gain can complicate outcomes in post-bariatric patients. Further IOM guidelines specific for post-bariatric surgery mothers would be useful for clinicians treating this expanding cohort of women.

Gestational Diabetes and Pre-eclampsia

Our findings support the established literature that BS is associated with significant reduction in major obesity-related pregnancy complications, most notably GDM and pre-eclampsia, compared to obese women without prior BS (15, 16). The prevalence of GDM after BS was 11% based on our findings from the largest known pooled sample in the literature. To contextualize this, the reported pooled global standardized prevalence of GDM is 14% across all pregnancies (6). Thus, BS reduces GDM risk to below the baseline population level. Furthermore, previous meta-analyses demonstrated that the risk of GDM increases with increased BMI in a dose-dependent pattern (31). Thus, our findings support the existing evidence by demonstrating that BS dramatically decreases pre-pregnancy BMI with an expected reduction in the odds of GDM.

While the pathophysiology of pre-eclampsia is thought to be linked with abnormal placentation, obesity and excessive weight gain are established risk factors. We found the odds of pre-eclampsia were 40% lower in the bariatric group than in controls. Previous literature has demonstrated similar findings (15).

These likely reflect the metabolic improvements attributed to the BRAVE effects described in the literature with the following components: bile flow alteration, reduction in gastric size, anatomical gut rearrangement and altered flow of nutrients, vagal manipulation, and enteric gut modulation (12, 22). Established literature supports remission of diabetes after BS, with RYGB superior in this outcome compared to LSG (12) and our findings underscore the preventative benefits of RYGB in reducing odds of GDM in pregnancy, through similar metabolic alterations described above.

Screening for GDM in post-bariatric surgery is nevertheless important, and a particular consideration is that standardized oral glucose tolerance testing (OGTT) is often poorly tolerated by women who have undergone procedures like RYGB, LSG and Biliary-pancreatic diversion as these can trigger dumping syndrome (30). Thus, alternative strategies such as multi-point home glucose monitoring and HbA1C may need to be considered (22, 30).

Delivery methods

The mode of delivery was significantly affected by a history of BS, with higher odds of requiring caesarean section and induction of labour in women post-bariatric surgery when compared to obese controls. While this may seem paradoxical it may reflect underlying obstetric risk factors, altered anatomy, or clinical decision-making biases, and the findings warrant further exploration to optimise delivery planning and counselling. Further studies stratifying the urgency of delivery and indications for C-section or labour induction would be beneficial to explore this association. Furthermore, instrumental delivery methods could be included in analysis in future reviews as previous literature has found BS reduces these odds significantly. There was insufficient data to analyze whether delivery methods were impacted by time interval from BS, and further studies would be helpful for both patients and clinicians.

Post surgical complications

Our meta-analysis found that rates of internal hernia after RYGB were low at 2%. And likewise, the rate of diagnostic laparoscopy during pregnancy was 3%. Previous evidence has reported that RYGB presents the greatest risk of surgical complications during pregnancy, with internal herniation occurring in 8% of post-surgical pregnancies and the most common location of the hernia was Petersen's space (22). This is a feared complication and previous reviews found that all maternal and perinatal deaths in pregnancies complicated by internal herniation after RYGB occurred in women treated later than 48 hours after symptom onset. Therefore, despite our findings of a lower incidence than previously reported, a high index of suspicion is required. The presentation may be non-specific, including abdominal pain and vomiting, thus all women of reproductive age undergoing RYGB should be thoroughly counselled on the lifelong risk of this complication to avoid delayed diagnosis and treatment (30). Should clinicians suspect the diagnosis of internal herniation, a multi-disciplinary approach is required when considering the risks versus benefits of diagnostic laparoscopy, CT imaging and even newer modalities such as 3D modelling to confirm diagnosis (32). Ultimately, delays in diagnosis will impact maternal and fetal outcomes, therefore balancing surgical risks, radiation exposure and anaesthetic risks all need careful consideration.

Another consideration, particularly in pregnancies after LSG is the greater risk of gastro-oesophageal reflux disease (GORD), which already occurs in up to two-thirds of pregnancies (33). While the condition itself is benign, it can significantly affect quality of life and can predispose to Barrett's oesophagus as a pre-malignant condition. In obese women, the effect of pregnancy hormones can exacerbate or cause de novo GORD, particularly in post-surgical mothers who have undergone LSG compared to RYGB (12, 34). Our review of the literature found that papers rarely assessed this maternal outcome, and further studies are needed to analyze the effects of timing of pregnancy after surgery and the differences according to surgery type on GORD incidence, severity and sequelae. While antacids, proton-pump inhibitors and Sucralfate are amongst the medical treatment options, refractory cases may require surgical approaches such as fundoplication, or magnetic sphincter augmentation, but further research is needed regarding the implications of these in pregnancy (33, 35).

Maternal nutrition

Our meta-analysis found the overall risk of clinically relevant anaemia to be 26% after all bariatric surgery. Specifically, the prevalence of iron-deficiency in post-surgical patients was 33%, albeit with notable variation between cohorts. The reported global prevalence of anaemia in pregnant women is 36.8%, thus our findings are in keeping with global averages (36). However, it is important to understand the pathophysiology of iron-deficiency anaemia (IDA) in BS, as these patients will have reduced production of hydrochloric acid in the stomach, which is necessary to convert dietary iron in the ferric form into the ferrous state. Furthermore, the reduced intake of meat and the reduction of intestinal iron absorption capacity due to bypassing are other contributors to the observed IDA (19). This can further exacerbate the physiological anaemia observed in pregnancy and certainly requires careful monitoring. Both Vitamin A and D deficiency were demonstrated with a high prevalence of 61% and 69% respectively. This is in keeping with established literature reporting that fat-soluble vitamin deficiencies (A, D, E, K) are common after bariatric surgery due to bypassing absorption sites, reduced bile mixing, and fat malabsorption (37). Vitamin D and A are most affected, with established associations in existing literature to bone, vision, and immune issues (38). Morgan et al. (2025) recently published guidance advising supplementation and blood-test monitoring of these nutrients in each trimester (30). This is essential given the high prevalences found in our study. Specifically regarding vitamin A, these pregnant women should avoid retinol/retinyl esters forms and instead take vitamin A exclusively in the beta-carotene form under medical supervision to prevent the risks of congenital anomalies (16, 39).

Neonatal Outcomes

Fetal Growth

Several important trends emerged in neonatal outcomes. As discussed above, infants born to mothers with prior BS had greater odds of IUGR and preterm birth. These findings support the hypothesis that rapid maternal weight loss and nutritional deficits may adversely affect fetal growth. Conversely, our study found that BS significantly reduced the odds of macrosomia, which is an expected benefit in this population based on existing literature. Overall, we found neonates born to women after BS weighed over 200g less than neonates born to obese mothers. This finding is consistent with previous meta-analyses in the literature (31, 40). These findings underscore the importance of antenatal nutritional monitoring, targeted supplementation and adherence to GWG targets, particularly in mothers who are within 12 months of BS who may be at greater risk for anemia and fat-soluble vitamin deficiencies described above.

APGAR scores, NICU admissions and peri-natal mortality

NICU admission rates (12%) and low Apgar scores < 7 at 5 min (1.7%) were both slightly elevated in the bariatric surgery cohort. While these rates were modest, they reflect a need for heightened neonatal

surveillance and underscore the importance of coordinated perinatal care. These variables may also reflect the confounding effects of both IUGR and prematurity on the risk of NICU admission.

Adopting a nuanced approach in this obstetric population may be prudent because although the odds of preterm birth did not significantly differ between early and late groups, there remains insufficient data on whether timing of pregnancy after BS correlates with IUGR, admission to NICU or perinatal mortality. More studies are needed to clarify the impact of BS on these critical clinical outcomes, perhaps modeling the time-interval from surgery to pregnancy as a continuous variable rather than a dichotomous cut-off.

Importantly, perinatal mortality rates were low (0.2%) and not significantly different between neonates born to women post-bariatric surgery compared to obese mothers, providing reassurance regarding overall fetal viability. A previous meta-analysis by Akhter et al. (2019) found the odds of perinatal mortality to be increased after BS (39). However, our results border on statistical significance and may nevertheless justify heightened clinical vigilance.

Timing of Conception Post-Surgery

Subgroup analyses based on time interval to conception (< 12 months vs. >12 months post-bariatric surgery) provided valuable clinical insights; however, their interpretation is constrained by heterogeneity across studies and limited sample sizes. Early conception within 12 months was associated with lower GWG, a non-significant increased odd of preterm birth, and no appreciable difference in the odds of GDM compared to later conception. These findings lend cautious support to current clinical guidelines recommending a minimum 12-month interval before conception to promote metabolic stabilisation and mitigate nutritional risks, which may be higher if the rapid weight loss phase post-surgery overlaps with early pregnancy. Nonetheless, future research should consider modeling time to conception as a continuous variable to better capture its relationship with maternal and neonatal outcomes, and to offer more nuanced guidance for clinical decision-making.

Study Quality and Limitations

The strength of this study includes the large pool of articles included in the original search. However, high heterogeneity in several analyses result from variability in study design, population characteristics, and surgical techniques, affecting generalizability. The limitations include the lack of RCTs and prospective data collection, smaller case-series, large heterogeneity in some analysis, unmeasured confounders and limited studies comparing early versus late conception at consistent intervals.

Lack of detailed data on nutritional status and micronutrient deficiencies stratified according to pregnancy timing and surgery type limits recommendations for post-bariatric surgery pregnancies. Reduced opportunity to conduct randomized controlled trials in this population limits evidence strength, relying on observational studies.

Most included studies were retrospective in nature (85.2%), introducing potential for selection, recall and reporting bias, confounding variables, and missing data. Although study quality was generally high per the Newcastle-Ottawa Scale, heterogeneity across outcomes was considerable ($I^2 > 80\%$ in many analyses), reflecting variation in patient characteristics, surgical procedures, definitions of outcomes, and follow-up protocols.

Importantly, many studies did not differentiate between specific types of bariatric procedures (e.g., LSG vs. RYGB), limiting the ability to draw procedure-specific conclusions. Given the distinct anatomical and absorptive alterations associated with different surgeries, future research should stratify by surgery type to enable more nuanced guidance.

Conclusion

This systematic review and meta-analysis demonstrates that BS prior to pregnancy significantly reduces the risk of obesity-related complications such as gestational diabetes, pre-eclampsia, and fetal macrosomia. However, BS is also associated with increased odds of caesarean delivery, labour induction, intrauterine growth restriction, NICU admission, and low Apgar scores, highlighting a complex balance of maternal and neonatal risks.

The substantial heterogeneity across studies reflects variations in surgical procedures, patient characteristics, and timing of conception, highlighting the importance of individualised care, multidisciplinary antenatal management, and robust preconception counselling. Nutritional deficiencies, particularly in iron and fat-soluble vitamins, were frequent and warrant vigilant monitoring and supplementation throughout pregnancy.

These findings support current guidelines recommending delayed conception for at least 12 months post-surgery to allow for nutritional stabilisation but emphasise the need for gestational weight gain guidelines tailored to this population. Critically, this review identifies key evidence gaps, including the need for high-quality prospective studies and refined analyses that model time from surgery to pregnancy as a continuous variable to account for the nuances of individual variation in weight stabilisation and better risk stratification. Addressing these gaps will advance clinical practice and support safer, more tailored care for women navigating pregnancy after bariatric surgery.

Declarations

Contributor and guarantor information

The study was conceived by MF and designed by MF, WL MK, YAA. The data was acquired and collated by MF, AR, CN, JHY, KW, SB and analysed by KW, SB, MF. The manuscript was drafted and revised critically for important intellectual content by all authors. All authors gave final approval of the version to be published. The corresponding author (MF) attests that all listed authors meet authorship criteria and

that no others meeting the criteria have been omitted. The guarantor (MF) accepts full responsibility for the work, had access to the data, and controlled the decision to publish.

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Competing interest declaration

The authors declare no conflict of interest with regards to the presented work.

Ethics approval and patient consent

Ethical approval was not required for this systematic review and meta-analysis.

Data availability statement

All data relevant to the study are included in the article or uploaded as supplementary information

Transparency declaration

The lead author (KW) affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained. All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organisations.

Patient Involvement and Dissemination

The research questions and outcomes were formulated based on patients' concerns and priorities. While patients were not directly involved in interpreting results or writing the article, efforts will be made to share findings with the lay audience through various channels, including press releases, social media, and authors' engagements with charities, public presentations and interviews.

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Table 1

Table 1. Summary of maternal and neonatal outcomes following bariatric Surgery: pooled proportions and comparative meta-analyses

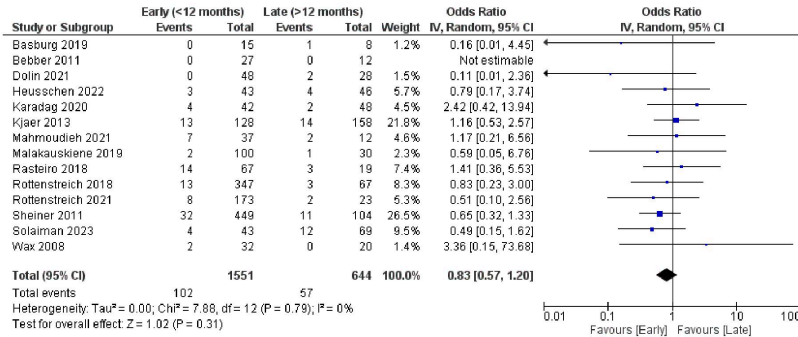
Pooled Outcome Rates in Women with a History of Bariatric Surgery		
Outcome	No. of Studies (n)	Effect Estimate (95% CI)
Gestational weight gain (kg)	106	9.66 [8.53, 10.79]
Gestational diabetes (GDM)	82	0.11 [0.10, 0.12]
Pre-eclampsia	54	0.05 [0.04, 0.08]
Caesarean section	95	0.39 [0.37, 0.40]
Induction of labour	13	0.28 [0.22, 0.34]
Postpartum haemorrhage	15	0.04 [0.04, 0.05]
NICU admission	74	0.12 [0.10, 0.14]
Preterm birth	78	0.101 [0.03, 0.11]
Intrauterine growth restriction (IUGR)	27	0.06 [0.05, 0.07]
Macrosomia	31	0.05 [0.04, 0.07]
Low APGAR (<7 at 5 min)	33	0.02 [0.01, 0.02]
Anaemia	19	0.26 [0.22, 0.31]
Vitamin deficiencies	12	0.04 [0.03, 0.05]
Internal hernia	11	0.02 [0.01, 0.04]
Diagnostic laparoscopy (hernia)	8	0.03 [0.01, 0.05]
Comparative Outcomes: Bariatric Surgery vs. Non-Surgical Controls		
Outcome	No. of Studies (n)	OR/Mean Difference (95% CI)
Gestational weight gain	21	−1.17 kg [−2.75, 0.40]
Gestational diabetes (GDM)	39	0.67 [0.53, 0.85]***
Pre-eclampsia	27	0.60 [0.45, 0.79]***
Caesarean section	41	1.24 [1.01, 1.52]*
Induction of labour	12	1.34 [1.08, 1.66]**
Postpartum haemorrhage	16	1.17 [0.64, 2.23]
NICU admission	24	1.39 [1.17, 1.65]**
Preterm birth	33	1.24 [1.04, 1.47]*
Birthweight	29	−205.38 [−224.86, −185.90]***
IUGR	13	2.09 [1.92, 2.27]***

Macrosomia	19	0.35 [0.24, 0.50]***
Low APGAR (<7 at 5 min)	13	1.38 [1.07, 1.79]**
Perinatal deaths	-	-

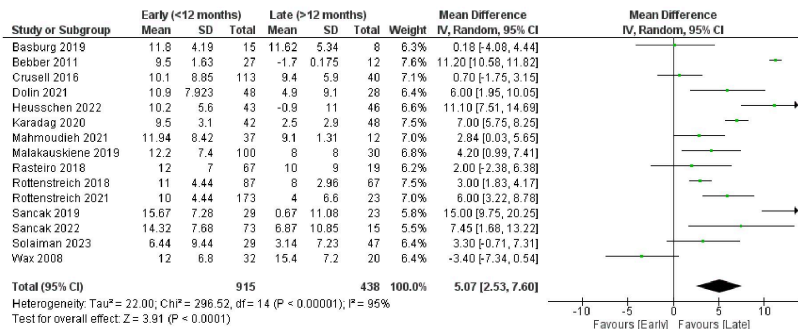
Pooled estimates were derived using a DerSimonian–Laird random effects model. Proportions represent pooled single-arm event rates among women with a history of bariatric surgery. Comparative estimates (ORs or mean differences) reflect outcome differences between bariatric surgery and non-surgical control groups. Studies reporting multiple surgical subgroups were included separately in pooled estimates if data were stratified. *p-value<0.05, ** p-value<0.01, *** p-value<0.001.

Figures

(a)



(b)



(c)

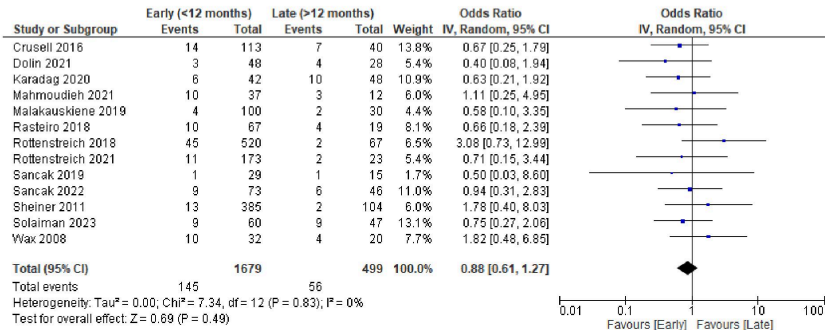


Figure 1

Comparative subgroup analysis forest plots on early (<12 months) vs late (>12 months) pregnancy post-op: (a) Gestational diabetes (GDM), (b) Gestational weight gain (GWG), (c) Preterm birth.

Supplementary Files

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