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Maternal and Neonatal Outcomes of Pregnancy within 7 years after Roux-en-Y Gastric Bypass or Sleeve Gastrectomy

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Abstract

Introduction: Few studies examine whether maternal and neonatal outcomes differ by time from metabolic and bariatric surgery (MBS) to conception. We describe maternal and neonatal outcomes among women with pregnancy after Roux-en-Y gastric bypass (RYGB) or sleeve gastrectomy (SG) overall and by whether conception occurred during the period when pregnancy is not recommended (<18 months postoperative) versus later.

Methods: A prospective cohort study enrolled 135 US adult women (median age, 30 years, body mass index [BMI], 47.2 kg/m^2) who underwent RYGB or SG (2006-2009) and subsequently reported ≥1 pregnancy within 7 years. Participants self-reported pregnancy-related information annually. Differences in prevalence of maternal and neonatal outcomes by postoperative conception timeframe (<18 versus ≥18 months) were assessed.

Results: Thirty-one women reported ≥2 postoperative pregnancies. At time of postoperative conception (median 26 [IQR:22-52] months postoperative) median BMI was 31 (IQR:27-36) kg/m^2. Excessive gestational weight gain (55%), cesarean section (42%) and preterm labor or rupture of membranes (40%) were the most common maternal outcomes. Forty percent of neonates had a composite outcome of still birth (1%), preterm birth (26%), small for gestational age (11%), or neonatal intensive care unit admission (8%). Prevalence of outcomes did not statistically significantly differ by timeframe.

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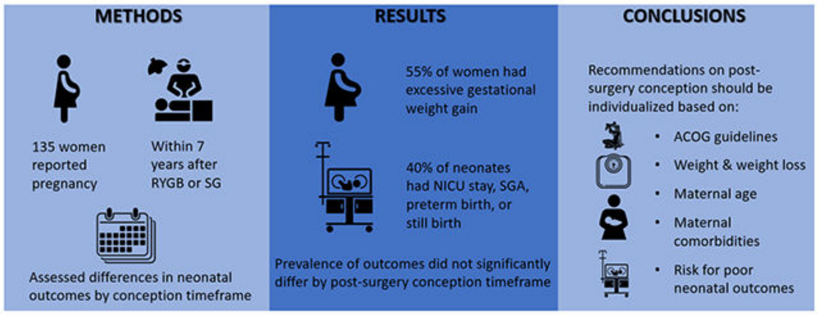
Conclusion: In US women who conceived ≤7 years following RYGB or SG, 40% of neonates had the composite neonatal outcome. The prevalence of maternal and neonatal outcomes post-MBS were not statistically significant by conception timeframe.

Graphical Abstract



Introduction

Among people with obesity, metabolic and bariatric surgery (MBS) before pregnancy reduces the risk of obesity-related maternal complications [1–3]. However, it is also associated with higher risk of preterm birth [1, 2, 4], small neonates [1–4], and neonatal intensive care unit (NICU) admission [2, 4], possibly related to the reduced absorption of micronutrients needed for fetal development [5, 6]. Micronutrient absorption is most hampered during rapid weight loss [7], which generally occurs in the first 6-12 months after MBS [8]. To optimize the likelihood of maternal weight stability during fetal development, multiple medical associations recommend people avoid conception for 12-18 months after MBS [9–11].

Despite meta-analyses of maternal and neonatal complications following MBS [1–4, 12], the impact of MBS on maternal and neonatal outcomes is not fully understood. Current literature is limited by restriction to full-term pregnancies, inclusion of outdated surgical procedures, and contradictory conclusions regarding some complications [1–3, 13, 14]. Few studies examine predictors of maternal and neonatal outcomes among MBS patients such as timing of conception in relation to MBS or weight change between surgery and conception. Furthermore, the prevalence of several maternal and neonatal outcomes (e.g., gestational weight gain, cesarean section, and NICU admission) vary by country, and little is known about these outcomes post-MBS in the United States.

Using data from a large US prospective cohort, the primary aim of this study is to describe maternal and neonatal outcomes among people who became pregnant with singletons after the most commonly performed bariatric surgical procedures, Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) [22], overall and by whether conception occurred during the postoperative period when pregnancy is not recommended (i.e., <18 months) versus later. The secondary aim is to identify predictors of postoperative neonatal outcomes (i.e., still birth, preterm birth, small for gestational age [SGA], and/or NICU admission).

Methods

The Longitudinal Assessment of Bariatric Surgery (LABS)-2, a multicenter prospective cohort study, recruited 2458 patients who were at least 18 years old and undergoing a first bariatric surgical procedure as part of routine clinical care at 6 clinical centers throughout the United States between 2005 and 2009. This report is restricted to participants who underwent RYGB or SG and who reported at least one postoperative singleton pregnancy within 7 postoperative years [16]. Recruitment methodology and study design have previously been described [8, 15–20]. Institutional review boards at each center approved the protocol and participants gave written informed consent. Study data are available at the NIDDK Central Repository [21]. The study is registered at ClinicalTrials.gov (NCT00465829).

Research assessments, which included anthropometric assessments, chart abstraction, interviews, and questionnaires, were conducted independent of surgical care within 30 days before scheduled surgery dates and annually after surgery for up to 7 years or until January 2015.

Assessments

Pregnancy determination in LABS-2 participants and relevant questionnaires have been described [16]. Participants reported postoperative pregnancies in the past 12 months on the annual Reproductive Health Questionnaire, or since surgery on the annual Short Form (administered beginning March, 2010) or Event and Complications Form (completed at the 4- or 5- year postoperative assessment). Immediately following report of a pregnancy, they were asked to complete the self-administered Reproductive Health Pregnancy (RHP) Questionnaire [21], which assessed the date of conception, due date and delivery or end date, and maternal and neonatal outcomes for each pregnancy [16]. Missing conception dates were imputed, as previously described [16, 17]. The RHP also asked people their weight when they became pregnant and weight change during pregnancy. This information was used to calculate 1) the percent weight loss from preoperative to conception, 2) the percent weight loss in the year prior to conception, 3) the percent weight gain during pregnancy, and 4) gestational weight gain. Definitions for these measures are in Supplemental Table 1.

On the RHP, the outcome of each pregnancy was reported as a live birth, still birth (fetus lost after 20 weeks or 5 months gestation), miscarriage (fetus lost before 20 weeks or 5 months gestation), ectopic or tubal pregnancy or abortion.

Maternal outcomes

Severe vomiting that required medication or hospitalization, preeclampsia or toxemia, gestational diabetes, cesarean delivery, and Intensive Care Unit (ICU) admission during or immediately after pregnancy were assessed with yes/no questions. Preterm labor or preterm rupture of membranes was defined as a “yes” response to either, “Did you go into preterm labor (contractions which started before 37 weeks of pregnancy with dilation of your cervix)?” or, “Did your water break prior to 37 weeks?” People who reported having a cesarean section were asked the main reason for the procedure.

We used American College of Obstetricians and Gynecologists (ACOG) recommendations for gestational weight gain for pregnancies to calculate the recommended weight gain per week for people with normal weight, overweight, and obesity [23]. Considering gestational age at delivery, gestational weight gain was defined as inadequate if the woman gained less weight than the ACOG recommended lower limit or excessive if they gained more than the ACOG recommended upper limit (Supplemental Table 1).

Neonatal outcomes

For each live birth, birth weight (in pounds and ounces), length (in inches), and presence of a birth defect, birth injury (e.g. fracture, dislocation, nerve damage), or NICU admission (each assessed with a yes/no question) were reported. Preterm birth was defined as live birth before 37 weeks gestation. Using birth weight reference for the United States (24), SGA is a neonate with a birthweight <10th percentile for a given gestational age at time of birth. Large for gestational age (LGA) is a neonate with a birthweight >90th percentile for a given gestational age at time of birth. Because neonatal outcomes were rare, we created a composite neonatal outcome that included still birth, preterm birth, SGA, and NICU admission.

Maternal and neonatal outcomes are reported for the entire postoperative period (i.e., 0-90 months) and stratified by the early postoperative period during which pregnancy is not recommended (<18 months, i.e., “early”) and the remaining follow-up period (18-90 months, i.e., “delayed”) [16].

Statistical analysis

Potential selection bias was examined by comparing preoperative characteristics of participants in the analysis sample to participants who reported a pregnancy but were excluded using the Pearson χ^2 test for categorical variables and the Wilcoxon rank-sum test for continuous variables. Because maternal and neonatal outcomes were evaluated at the pregnancy level (i.e., some participants contributed more than one pregnancy) the assumption of independence was violated. Therefore, we calculated 95% confidence intervals (CI) for proportions with maternal and neonatal outcomes using the Wilson score method [25] overall and by postoperative timeframe (i.e., early [<18 months] versus delayed [18-90 months]). To determine statistically significant differences by timeframe, we evaluated whether 95% CI for estimates overlapped. We performed sensitivity analyses restricting the analysis sample to the first postoperative conception.

We calculated median number of months from surgery to conception for neonates with versus without SGA and LGA, respectively.

Statistical power to evaluate predictors of individual neonatal outcomes was insufficient. Therefore, we used Poisson mixed models with robust error variance and person-level random intercept to examine associations of maternal, surgical, and pregnancy characteristics with the composite neonatal outcome. The following independent variables were evaluated in separate models: maternal age and BMI at time of conception, whether conception was early (vs. delayed), percent weight loss from preoperative to conception, estimated percent weight loss in the year prior to conception, insufficient gestational weight gain, excessive gestational weight gain. Given collinearity between weight change variables, a multivariable model was tested with all variables except estimated percent weight change in the year prior to pregnancy. P-values are two-sided. Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

One hundred and thirty people reported 198 pregnancies during 7 years of follow-up. Pregnancy outcome data was available for 112 participants (86%) and 157 pregnancies (79%) of all known pregnancies (Figure 1). 5 people were excluded from analysis for only having twin pregnancies; 3 other twin pregnancies were excluded. The remainder of this manuscript only reports on singleton pregnancies. Seventy-seventy participants (72%) reported 1 pregnancy, 19 (18%) reported 2 pregnancies, 10 reported 3 pregnancies (9%), and 1 reported 4 pregnancies during the 7-year follow-up period.

Preoperative characteristics of participants included in (N=107) and excluded from (N=23) the analysis are shown in Table 1. Participants excluded from the analysis sample versus those included were significantly more likely to have lower household income and not have medical insurance.

In the analysis sample, 56.1% of participants underwent RYGB or SG in 2006-2007, and 43.9% in 2008-2009. At time of surgery, the median age was 30 years and median BMI was 48.9 kg/m^2. Most participants underwent RYGB (97.2%). Median time from surgery to conception of first postoperative singleton pregnancy was 28.6 months (IQR: 16.5-43.2, range: 1.4-81.5).

Median time from surgery to all conceptions (N=149) was 35.7 months (IQR: 22.4-52.2, range: 1.4-81.5). Sixteen participants (15.0%) had a pregnancy within 12 months of surgery and 31 (29.0%) had a pregnancy within 18 months. At the time of conception, the median age was 33 years and median BMI was 30.6 kg/m^2 (Table 2). The median percent weight loss from preoperative to conception was 35.5% (IQR: 28.1-43.0). The median estimated percent weight loss in the year prior to conception was 0.0% (IQR: −6.2, 5.8). Median estimated percent weight loss in the year prior to conception was lower in the delayed versus early conception timeframes (Table 2).

Maternal Outcomes

The median percent weight gain during pregnancy was 12.4% (IQR: 2.8-18.5, range: −18.2%−70.2%) and the median weight gain in pounds was 22.0 (IQR: 3.0-35.0, range: −40.0-80.0). Both were similar during each timeframe (data not shown).

Two participants (1%) reported ectopic pregnancies and 11 (8%) reported having an abortion. Nineteen percent of pregnancies ended in miscarriage. The most common maternal complications following pregnancies of any duration (N=149) were preterm labor or rupture of membranes (40%), cesarean section (42%), and excessive gestational weight gain (55%; Table 3). Of participants with preterm labor or preterm rupture of membranes, 61.9% (95% CI: 46.8-75.0) also had preterm delivery. The primary self-reported reasons for the cesarean sections were prior cesarean section (45%), breech fetus (18%), fetus in distress (18%), labor not progressing (5%), or other (15%; i.e., high risk delivery due to birth defect, nutritional deficiency, preeclampsia, low amniotic fluid, or placenta previa).

Insufficient gestational weight gain appeared more common in early than delayed conceptions (45% [95% CI:28-63] versus 26% [95% CI:18-35]). In contrast, excessive gestational weight gain appeared less common in early versus delayed pregnancies (38% [95% CI:23-56] versus 60% [95% CI:50-69]). However, for both outcomes, 95% CIs overlapped so differences by time period were not statistically significant. All other maternal complications had similar prevalence during the early and delayed conception timeframes or were too rare to evaluate (i.e., ectopic pregnancy, preeclampsia, ICU admissions) (Table 3).

Neonatal Outcomes

The most common neonatal outcomes were preterm birth (26%) and LGA (17%, Table 3). Approximately 11% of neonates had SGA and 8% had a NICU admission. Preterm birth, LGA, and NICU admission appeared more prevalent in the delayed timeframes while SGA was less prevalent (Table 3). However, 95% CIs overlapped so differences were not statistically significant. Still birth (1%), birth defects (4%), and birth injuries (1%) were rare and could not be compared between timeframes. The median gestational age at delivery in this cohort was 37 weeks; 36 (IQR:33-36) weeks for preterm births and 39 (IQR:38-40) weeks for full term births.

For neonates with versus without SGA, the median number of months from surgery to conception was 17.3 (IQR:10.9-43.0) versus 39.5 (IQR:22.4-53.6) months, respectively. For neonates with versus without LGA, the median number of months from surgery to conception was 42.3 (IQR:32.3-57.6) versus 33.6 (IQR:16.8-53.4) months, respectively.

The sensitivity analysis examining maternal and neonatal outcomes in the first postoperative pregnancy yielded similar results to the main analysis (Supplemental Table 2).

Factors Associated with Poor Neonatal Outcomes

Higher BMI at time of conception (aRR=0.48, 95% CI 0.27-0.86) and excessive gestational weight gain (aRR=0.54, 95% CI 0.33-0.90) were independently associated with lower risk of the composite neonatal outcome (Table 4).

Discussion

In this US cohort of 112 people with at least one singleton pregnancies pregnant within 7 years following RYGB or SG, 29% of people conceived (n=31) within 18 months of surgery despite current recommendations that people avoid conception during this timeframe [10, 11, 26]. However, 56% of our cohort conceived prior to these recommendations being published (i.e., had surgery in 2006-2007).

Excessive gestational weight gain, cesarean section, and preterm labor or rupture of membranes were the most common adverse maternal outcomes in this cohort. Our prevalence of excessive gestational weight gain (55%) is similar to estimates for the general

US population of pregnant people with pre-pregnancy obesity (58%) and slightly higher than estimates for the general US population of pregnant people who deliver full-term (48%) [27] and US people post-MBS who delivered ≥20 weeks gestation (N=1886; 48%) [14], despite our study including all pregnancies, >20% which were <20 weeks. The proportion of births that were cesarean section in our cohort (42%) was the same as that for the general US population with obesity (43%) [28]. However, two studies have found that people post-MBS had lower risk of cesarean section, particularly emergency cesarean section, when compared to preoperative BMI-matched controls [13, 14]. Most cesarean sections in this cohort (63%) were non-emergency (i.e. due to a prior cesarean section or breech fetus). Overall, cesarean delivery rates are higher in people with obesity [29] and median BMI in our cohort even after MBS fell into the obese category.

Forty percent of neonates in this cohort had the composite neonatal outcome (i.e., still birth, preterm birth, SGA, and/or NICU admission), confirming that people who have undergone MBS are at high-risk of adverse neonatal outcomes. Preterm birth (26%) and LGA (17%) were most common. NICU admission appeared less likely to occur in the early than delayed conception timeframe though differences were not statistically significant. Results from a US cohort [14] found higher NICU admission rates >2 years than <1-year post-MBS (13% versus 10%, respectively). The maximum length of time between conception and MBS was not reported in that cohort [14]; the higher prevalence in the later timeframe may be related to increasing maternal age [30]. A recent scoping review concluded there was no clear association between time from MBS to conception and preterm birth because studies found associations in both directions [31].

Consistent with other research [14], we found that LGA appeared less common and SGA more common in the early versus delayed conception timeframe. Though our findings were not statistically significant, the higher prevalence of SGA in the <18-month timeframe support recommendations that people postpone pregnancy at least 18 months following MBS. The higher prevalence of LGA in the delayed conception timeframe may be at least partially explained by people being in a period of weight regain at time of conception, having higher BMI, or having gestational diabetes.

The prevalence of preterm birth in our cohort (26%) is higher than in the general US population of pregnant people with obesity (8%), which includes multiple gestations,[32] and other cohorts of people with pregnancy post-MBS (10% in Sweden [33] and 11% in the US [14]). Most preterm births in our cohort occurred at 35-36 weeks gestation (68%), which may explain why NICU admissions were less common (8%) than preterm birth. The prevalence of preterm birth was consistent across the early versus delayed postoperative conception groups (22% versus 27%, respectively). Unfortunately, we are unable to determine the number of spontaneous versus medically-indicated preterm births. However, 40% of participants in our cohort reported preterm labor or rupture of membranes suggesting that spontaneous preterm birth may have been common. This is supported by findings from a Swedish study that people with pregnancy post-MBS had a significantly higher risk of spontaneous but not medically-indicated preterm birth than controls [34].

Contrary to expectation, excessive gestational weight gain was independently associated with lower risk of the composite neonatal outcome. In the general population and in a retrospective cohort study of French people post-MBS, insufficient gestational weight gain was associated with higher rates of preterm birth and SGA [35, 36]. This is also inconsistent with findings from Wang et al. that showed higher infant morbidity among women with both insufficient and excessive gestational weight gain, even among women with obesity [37]. Because people may gain or lose a large percentage of their weight during a postoperative pregnancy, gestational weight gain recommendations for patients post-MBS may need to be individualized based on pattern of weight change. In addition to excessive gestational weight gain, higher BMI at time of conception was independently associated with lower risk of the composite neonatal outcome. This may be because people with higher BMI were not in a period of impaired micronutrient absorption at time of conception.

This study is subject to the following limitations. First, data are self-reported, not verified by medical records, and subject to recall bias. However, research shows high reliability of patient-reported pregnancy outcome data [38]. Second, because poor maternal and neonatal outcomes were so rare, we were underpowered to examine factors associated with individual maternal and neonatal outcomes. Third, we do not have a non-surgical control group with a similar BMI with which to compare findings. Additionally, most pregnancies in the early conception group occurred 12-18 months after surgery which limited our statistical power and likely hampered our ability to detect statistically significant differences by timeframe. However, given clinical care guidelines to delay pregnancy 12-18 months postoperative, a very large cohort would be required to yield enough conceptions <12 months after surgery for evaluation. Finally, while SG is the most commonly performed metabolic and bariatric procedure performed in the United States today, reflecting the enrollment period (2006-2009) we only had a small number SG in this cohort. Future research should specifically examine pregnancy outcomes following SG. Strengths of this study include the repeated measures of weight, which allowed us to look at weight change during different timeframes, the examination of a large number of maternal and neonatal outcomes, and the examination of maternal and neonatal outcomes by postoperative conception timeframe.

Conclusions

Two in five singleton neonates in this US cohort born to people who had undergone MBS had still birth, preterm birth, SGA, and/or NICU admission. While the optimal timing for post-MBS pregnancy is unknown, some maternal and neonatal outcomes appeared to differ in the early versus delayed postoperative conception timeframe. People who become pregnant after MBS should be counseled according to ACOG Clinical Management Guidelines [9] and recommendations regarding conception post-MBS should be individualized based on weight, weight loss, maternal age, maternal comorbidities, and risk for poor neonatal outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Key Points:

- Approximately half of pregnant people (55%) had excessive gestational weight gain.
- 40% of neonates had still birth, preterm birth, small for gestational age, and/or NICU admission.
- Prevalence of maternal and neonatal outcomes did not differ by conception timeframe.

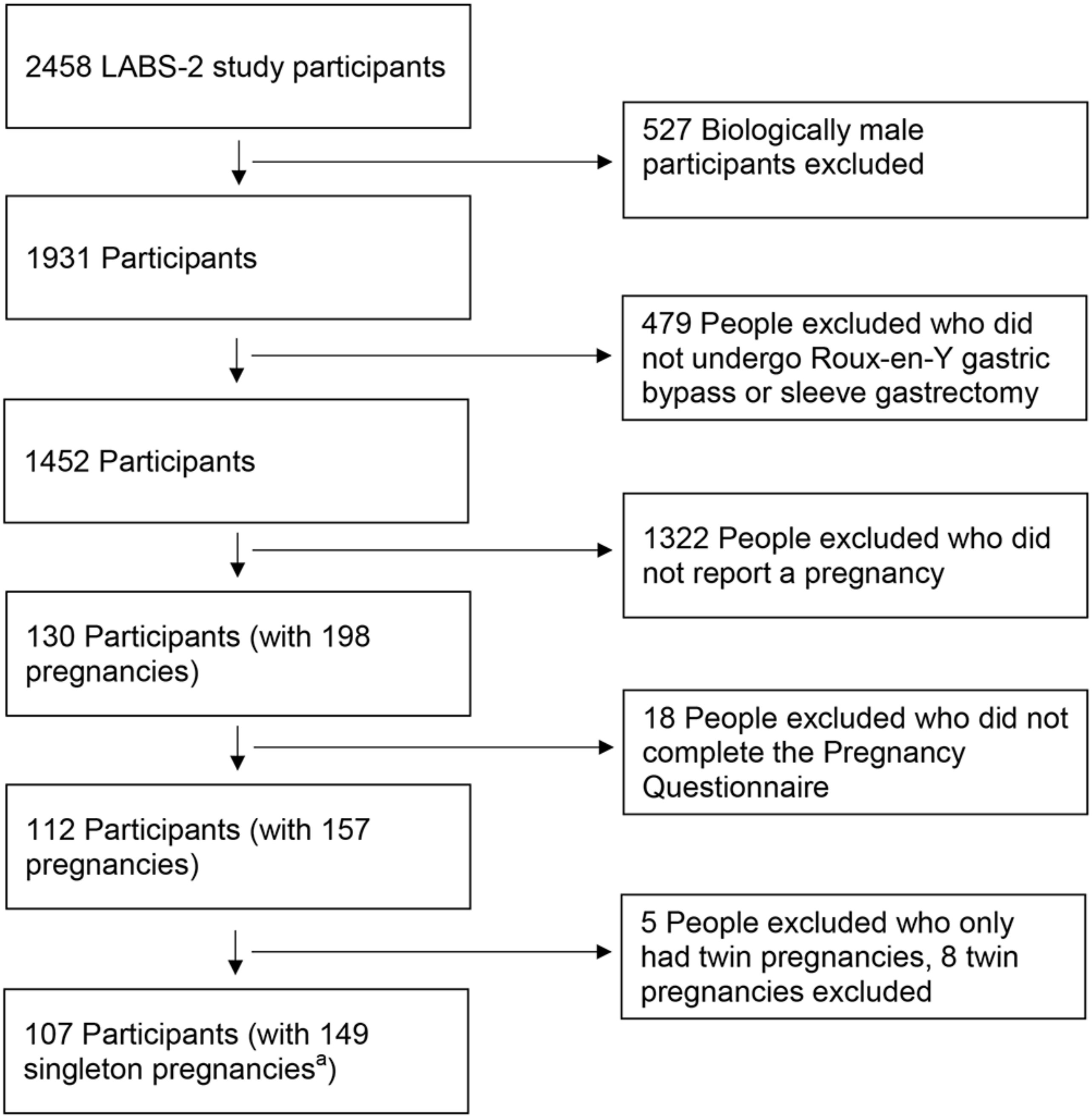

Figure 1.

Longitudinal Assessment of Bariatric Surgery-2 (LABS-2) Study Flow from Enrolled Participants to Analysis Sample

[a] 77 participants reported 1 pregnancy; 30 reported 2 or more.

Table 1.

Preoperative characteristics and surgical procedure of women with at least one pregnancy ≤ 7 years after Roux-en-Y gastric bypass or sleeve gastrectomy included in and excluded from the analysis sample

	Included (n=107)	Excluded (n=23)
Characteristic	**No. %**	**No. %**
Age, years		
Median (25th-75th %tile)	30 (26-33)	28 (25-31)
Range	20-41	19-38
Race/ethnicity		
Non-Hispanic white	75 (70.1)	20 (87.0)
Non-Hispanic Black	14 (13.1)	2 (8.7)
Hispanic	14 (13.1)	1 (4.4)
Non-Hispanic other	4 (3.7)	0 (0.0)
Education		
≤ High school	16 (16.5)	4 (17.4)
Some college	51 (52.6)	13 (56.5)
≥ College degree	30 (30.9)	6 (26.1)
Household income *		
<$25,000	14 (14.9)	8 (36.4)
$25,000-$49,999	41 (43.6)	5 (22.7)
≥$50,000	39 (41.5)	9 (40.9)
Relationship status		
Married or living as married	48 (49.5)	7 (30.4)
Divorced or separated	16 (16.5)	2 (8.7)
Never married	33 (34.0)	14 (60.9)
Medical insurance *		
No insurance	0 (0.0)	4 (18.2)
Government	17 ()	4 (13.6)
Private	69 (71.1)	10 (45.5)
Other/unknown insurance type	11 (11.3)	4 (18.2)
Body mass index, kg/m^2		
Median (25th-75th %tile)	48.9 (44.1-52.9)	48.9 (43.4-54.6)
Range	36.6-72.5	39.9-75.1
Surgical procedure		
Roux-en-Y gastric bypass	104 (97.2)	22 (95.7)
Sleeve gastrectomy	3 (2.8)	1 (4.4)

Denominators shift between variables as a result of missing data.

* Statistically significant difference (p<.05) between those included in and excluded from analysis sample; p for income =0.04, p for medical insurance <.001

Table 2.

Characteristics of 107 women at the time of each singleton post-Roux-en-Y gastric bypass or sleeve gastrectomy conception (N=149), overall and by early versus delayed conception timeframe

Characteristic	Overall (0-90 months postoperative) (N=149[a])	Conception in relation to Roux-en-Y gastric bypass or sleeve gastrectomy	
		Early (<18 months postoperative) (n=31[b])	Delayed (18-90 months postoperative) (n=115)
Age, years			
Median (25^{th}-75^{th} percentile)	33 (29-36)	31 (27-35)	34 (30-36)
Range	22-47	22-40	23-46
Body mass index, kg/m^2			
Median (25^{th}-75^{th} percentile)	30.6 (27.4-35.7)	29.3 (24.5-36.6)	31.1 (28.2-35.7)
Range	19.0-59.1	20.7-45.8	19.0-59.1
% weight loss from preoperative			
Median (25^{th}-75^{th} percentile)	35.5 (28.1-43.0)	39.9 (25.1-45.4)	33.8 (28.1-39.5)
Range	7.6-63.2	17.0-53.2	7.6-63.2
Estimated % weight loss year prior to conception[c]			
Median (25^{th}-75^{th} percentile)	0.0 (−6.2-5.8)	15.1 (11.0-30.7)	−1.5(−7.5-1.4)
Range	−20.5-49.3	1.9-49.3	−20.5-17.6

[a] Women who had more than one singleton pregnancy (30 of 107) are included multiple times with data specific to each pregnancy.

[b] Sixteen pregnancies were within 12 months of bariatric surgery.

[c] Weights exactly one year prior to start of pregnancy were unavailable. Weight change was estimated by multiplying weight change between 1) weight at time of pregnancy and 2) the weight measured closest to one year prior to conception (range 182-548) by the ratio (actual number of days between weight measurements)/365.25. A negative number reflects weight gain.

Table 3.

Maternal and neonatal outcomes in 149 singleton pregnancies among 107 mothers[a] within 7 years following Roux-en-Y gastric bypass or sleeve gastrectomy, overall and by early versus delayed conception timeframe

			Conception in relation to Roux-en-Y gastric bypass or sleeve gastrectomy			
	Overall (0-90 months postoperative)		Early (<18 months postoperative)		Delayed (18-90 months postoperative)	
Maternal and neonatal outcomes	**n**	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**
Severe vomiting	20	13.9 (9.2-20.5)	3	10.0 (3.5-25.6)	15	13.5 (8.4-21.1)
Preeclampsia or toxemia	3	2.1 (0.7-6.1)	0	0.0 (0.0-11.7)	3	2.8 (0.9-7.9)
Gestational diabetes	9	6.3 (3.3-11.5)	1	3.2 (0.6-16.2)	8	7.3 (3.7-13.7)
ICU admission	3	2.1 (0.7-5.9)	2	6.5 (1.8-20.7)	1	0.9 (0.2-4.9)
Preterm labor or rupture of membranes	42	40.4 (31.5-50.0)	13	54.2 (35.1-72.1)	28	35.9 (26.1-47.0)
Cesarean section	43	42.2 (33.0-51.9)	9	37.5 (27.4-60.8)	34	44.2 (33.6-55.3)
Insufficient gestational weight gain[b]	39	30.2 (23.0-38.6)	13	44.8 (28.4-62.5)	26	26.0 (18.4-35.4)
Excessive gestational weight gain	71	55.0 (46.4-63.4)	11	37.9 (22.7-56.0)	60	60.0 (50.2-69.1)
Still birth	2	0.7 (0.1-3.8)	0	0.0 (0.0-11.0)	1	0.9 (0.2-4.9)
Preterm birth	26	25.5 (18.0-34.7)	5	21.7 (9.7-41.9)	21	26.6 (18.1-37.2)
Small for gestational age	10	10.5 (5.8-18.3)	5	22.7 (10.1-43.4)	5	6.9 (4.7-18.5)
Large for gestational age	16	16.8 (10.6-25.6)	1	4.6 (0.8-21.8)	15	20.6 (12.9-31.2)
Birth defect	4	3.8 (1.5-9.5)	1	4.0 (0.7-19.5)	3	3.9 (1.3-10.7)
Birth injury	1	1.0 (0.2-5.2)	1	4.0 (0.7-19.5)	0	0.0 (0.0-4.7)
NICU admission	8	7.7 (3.9-14.4)	1	4.0 (0.7-19.5)	6	7.7 (3.6-15.8)
Composite outcome[c]	41	40.6 (31.5-50.3)	10	43.5 (25.6-63.2)	30	39.0 (28.8-50.1)

ICU, Intensive Care Unit; NICU, Neonatal Intensive Care Unit

[a] 30 women contributed more than 1 singleton pregnancy.

[b] Considering weeks of gestation, gestational weight gain was defined as inadequate if the woman gained less weight than the Institute of Medicine recommended lower limit and excessive if they gained more than the recommended upper limit recommended (see Supplemental Table 1).

[c] Includes still birth, preterm birth, small for gestational age, and NICU admission.

Table 4.

Unadjusted and adjusted associations between maternal, surgical, and pregnancy characteristics and the composite neonatal outcome[a] among 149 singleton pregnancies among 107 mothers within 7 years following Roux-en-Y gastric bypass or sleeve gastrectomy

Characteristics	RR (95% CI)	P	aRR (95% CI)	P
Age at conception, per 10 years older	0.90 (0.56-1.44)	0.65	0.82 (0.47-1.44)	0.49
Body mass index at conception kg/m^2, per 10 units more	0.80 (0.53-1.20)	0.28	0.48 (0.27-0.86)	0.01
Early versus delayed conception	1.00 (0.61-1.64)	0.99	1.22 (0.81-1.82)	0.34
Percent weight loss from preoperative to conception, per 10%	0.95 (0.74-1.22)	0.70	0.75 (0.51-1.10)	0.14
Estimated percent weight loss in year prior to conception, per 10%	1.05 (0.86-1.29)	0.60		
Insufficient gestational weight gain	1.27 (0.72-2.22)	0.40	0.88 (0.64-1.21)	0.44
Excessive gestational weight gain	0.58 (0.37-0.91)	0.02	0.54 (0.33-0.90)	0.02

RR, relative risk; aRR, adjusted relative risk

[a] Includes still birth, preterm birth, small for gestational age, and NICU admission.