Maternal impacts and perinatal outcomes after three types of bariatric surgery at a single institution

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Abstract

Purpose Bariatric surgery is widely known to improve pregnancy outcomes and to increase the risk of having small for gestational age neonates. However, the specific causes of neonatal growth restriction are still unclear. This study aimed to investigate the impacts of bariatric surgery on pregnancy and perinatal status at a single institution.

Methods 24 women delivered singleton births among the 193 reproductive-aged women who underwent bariatric surgery. We classified the surgery into three types: laparoscopic adjustable gastric banding (LAGB; $n = 6$), laparoscopic sleeve gastrectomy (LSG; $n = 5$), and malabsorptive surgery (MS; $n = 13$), and investigated the pregnancy complications and perinatal impacts.

Results The median maternal weight gain after LAGB was 12.5 kg (LSG 6.9 kg, MS 9.0 kg). Gestational hypertension was observed in half of the women who underwent LAGB, but in none of those who underwent MS. No significant difference in neonatal birth weight was observed between the LAGB (median 3272 g) and LSG (median 3005 g) groups. The maternal impact after MS was a remarkable decrease in hemoglobin during prepregnancy (median 1.9 g/dl). About 69% of women developed gestational anemia after MS, and their neonatal birth weight was the lowest (median 2660 g). However, the birth weight of neonates delivered by mothers without anemia after undergoing MS was similar to that of those delivered by mothers after undergoing other types of bariatric surgery (median 3037 g).

Conclusions Maternal anemia after MS may lead to low neonatal birth weight, which could be attributed to the large-scale reduction in maternal micronutrient levels.

Keywords Bariatric surgery · Gestational anemia · Neonatal birth weight · Sleeve gastrectomy

Introduction

Obesity has been widely known as one of the major factors associated with infertility in reproductive-aged women [1]. Furthermore, maternal obesity is a risk factor for gestational diabetes, hypertension, or preeclampsia, increasing the risk of delivery complications, stillbirth, preterm birth, neonatal macrosomia, and some congenital malformations [2-5].

According to the published reports, bariatric surgery has been commonly used as a weight loss method associated with long-term metabolic remission [6]. Therefore, the American College of Obstetrics and Gynecology recommends losing weight prior to conception and acknowledges bariatric surgery as promising in prepregnancy obesity treatment [7]. However, some reports recently presented the risk of having small neonates, preterm birth, and maternal anemia after bariatric surgery [8, 9]. Furthermore, Swedish studies reported similar perinatal outcomes after bariatric surgery in a large population [10, 11]. Although the Swedish studies were clinically significant for bariatric surgeons and obstetricians, there was a bias in the type of surgical procedure, of which 98% were gastric bypasses [11]. However, there are several types of bariatric procedures performed worldwide [12], necessitating the need to evaluate the different maternal impacts and pregnancy outcomes of each procedure. This retrospective study aimed to investigate the

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pregnancy impacts and perinatal outcomes according to the surgical procedure at a single institution.

Materials and methods

This is a single-center retrospective case–control study investigating 24 women who gave singleton births among the 193 reproductive-aged women after undergoing four procedures [laparoscopic adjustable gastric banding (LAGB), laparoscopic sleeve gastrectomy (LSG), laparoscopic Roux-en-Y gastric bypass (LRYGB), and LSG with duodenojejunal bypass (LSG/DJB)] from October 2005 to October 2014. All singleton pregnancies during the postoperative period were reported, and questionnaire surveys regarding the physical data of mothers and neonates as well as complications in terms of the pregnancy and delivery among 33 singleton pregnancies were obtained from the mothers, who provided informed consent for this study.

For the evaluation of the pregnancy impacts depending on the surgical procedure, we extracted data from only 24 pregnancies, which was the first pregnancy in mothers among 33 singleton births, and divided the patients according to the type of surgery they underwent [LAGB; LSG; and malabsorptive surgery (MS), including LRYGB and LSG/DJB] and compared the difference in weight loss, remission of metabolic comorbidities in the postoperative period, complications of pregnancy and delivery, and neonatal birth weight.

In addition, we also investigated the maternal hemoglobin and serum iron levels for all types of surgery during prepregnancy as well as the relationship between the neonatal birth weight and maternal anemia.

Anemia definition

Anemia was defined using the age- and gender-specific World Health Organization criteria (hemoglobin < 12 g/dl in adult women and 11 g/dl during pregnancy).

Gestational diabetes mellitus definition

The women were diagnosed to have overt diabetes during pregnancy when their glycosylated hemoglobin is ≥ 6.5% [13].

Gestational hypertension definition

Gestational hypertension was defined as systolic blood pressure over 140 mmHg or diastolic blood pressure over 90 mmHg during pregnancy.

Patients and treatment

We recommended that all patients regularly take supplements (iron, zinc, vitamins, folate, calcium, etc.) after all types of surgery and strictly ordered the patients who underwent MS to continue taking supplementations indefinitely. We asked the reproductive-aged women to avoid pregnancy for 18 months and consult us with regard to the appropriate time for conceiving should they wish to get pregnant after surgery. When patients reported pregnancy after LAGB, they were asked to visit our center to completely loosen the tight banding to prevent dehydration and nutritional deficiencies, and no additional adjustment was performed during pregnancy unless the patients requested re-tightening.

Micronutrient supplementation

Based on the standard minimum daily requirement for Japanese women, our recommended supplementations included elementary iron (12 mg), folic acid (200–400 μg), and vitamin B12 (1000 μg). In case of nutritional deficiencies, we usually prescribe the appropriate supplementation for treatment.

Statistical analysis

Descriptive results regarding continuous variables were reported as the median and interquartile range (IQR) and were analyzed using the Kruskal–Wallis and Steel–Dwass tests. All tests were two-sided and a p value of < 0.05 indicated a statistically significant difference.

Results

The number of women who underwent LAGB was 6, LSG 5, and MS 13, with their characteristics being described in Table 1. The physical findings at the preoperative stage among the three groups were similar, except for age. The median % total weight loss (TWL) was, respectively, 7.8% (IQR 7.0–23.6) for LAGB, 30.0% (IQR 29.4–35.9) for LSG, and 36.0% (IQR 32.6–39.0) for MS, with significant differences in %TWL and postoperative body mass index (BMI) between LAGB and the other procedures.

Preoperative comorbidities and complete remission during prepregnancy are described in Table 2. Type 2 diabetes mellitus and hypertension were completely controlled during prepregnancy in women who underwent MS. However, hypertension was completely resolved in only approximately half of the women after LAGB and LSG.

Table 1 Maternal characteristics at pre-operation and prepregnancy

Types of procedure (number of mothers)	LAGB (n = 6)	LSG (n = 5)	MS (n = 13)	p value
Pre-operation				
Physical findings[a]				
Age, years	26 (24–27)	33 (31–33)	30 (27–32)	< 0.05[b]
Body weight, kg	95.9 (88.9–121.7)	94.3 (92.9–101.8)	106.3 (93.8–139.7)	NS (0.71)[b]
BMI, kg/m^2	39.7 (34.5–44.9)	36.8 (35.4–38.7)	42.0 (35–43.3)	NS (0.67)[b]
Number of positive proteinuria	0	0	0	NS
Prepregnancy				
Surgery to conception interval[a], months	28 (23–39)	26 (25–39)	18 (16–27)	NS (0.21)[b]
Physical findings[a] (at conception)				
Age, years	28 (26–31)	35 (34–37)	31 (30–33)	< 0.04[b]
Body weight, kg	82 (80.5–83.5)	65 (62.0–67.0)	65 (62.0–73.0)	< 0.03[b]
BMI, kg/m^2	31.2 (31.0–32.8)	24.8 (23.3–27.4)	26.3 (24.9–29.0)	< 0.01[b]
Weight loss after surgery[a] (at conception)				
Weight loss, kg	8.1 (6.9–24.5)	28.7 (26.3–35.4)	38.3 (29.7–49.7)	< 0.01[b]
%TWL, %	7.8 (7.0–23.6)	30.0 (29.4–35.9)	36.0 (32.6–39.0)	< 0.01[b]

LAGB laparoscopic adjustable gastric banding, *LSG* laparoscopic sleeve gastrectomy, *MS* Roux-en-Y gastric bypass and LSG with duodenojejunal bypass, *NS* not significant

[a]Median (IQR) BMI; body mass index, %TWL; %total weight loss

[b]Kruskal–Wallis test

Table 2 Preoperative comorbidities and complete remission at prepregnancy

Preoperative comorbidities (n) (n/number of mothers)	LAGB	LSG	MS
Type 2 diabetes mellitus (%)	0 (0)	0 (0)	6 /13 (46)
Hypertension (%)	5/6 (83)	2/5 (40)	10/13 (77)
Dyslipidemia (%)	2/6 (33)	4/5 (80)	9/13 (69)
Complete remission (CR–*number*) (CR–*number*/n)			
Type 2 diabetes mellitus (%)	0 (0)	0 (0)	6/6 (100)
Hypertension (%)	3/5 (60)	1 /2 (50)	10/10 (100)
Dyslipidemia (%)	1/2 (50)	3 /4 (75)	6/9 (67)

Complete remission Type 2 diabetes mellitus; HbA1c < 6.0%, fasting blood glucose < 100 mg/dl without medications. Hypertension; BP < 120/80 mmHg without medications. Dyslipidemia; LDL-C < 130 mg/dl, HDL-C ≥ 40 mg/dl, TG < 150 mg/dl without medications

LAGB laparoscopic adjustable gastric banding, *LSG* laparoscopic sleeve gastrectomy, *MS* Roux-en-Y gastric bypass and LSG with duodenojejunal bypass, *HbA1c* glycosylated hemoglobin, *BP* blood pressure, *LDL-C* low-density lipoprotein cholesterol, *HDL-C* high-density lipoprotein cholesterol, *TG* triglyceride

Maternal weight changes and complications among 24 pregnancies are described in Table 3. The weight gain (median 12.5 kg, IQR 9.8–20.5) and maximum body weight (median 98 kg, IQR 91.5–106) during pregnancy in patients who underwent LAGB was significantly different compared with that in patients who underwent LSG (weight gain, median 6.9 kg; maximum body weight,

median 68.9 kg) and MS (weight gain, median 9.0 kg; maximum body weight, median 73.5 kg). However, no difference was observed between the LSG and MS groups.

The most frequent pregnancy complication, especially after undergoing MS, was anemia (69%), and two patients were diagnosed with severe anemia during pregnancy (hemoglobin levels under 8.0 g/dl). Except for one patient who only had mild anemia, the patients had been continuously taking iron supplements including vitamins and minerals after surgery. Gestational diabetes mellitus was not observed in patients who underwent MS. However, two patients who underwent LSG, of whom none had type 2 diabetes mellitus during the preoperative period, had progressed to gestational diabetes mellitus, and one patient was treated for impaired glucose tolerance after delivery. HELLP (hemolysis, elevated liver enzymes, lowered platelets) syndrome was noted in only one patient who underwent LAGB but did not have hypertension during prepregnancy. Gestational hypertension was observed in half of the patients who underwent LAGB, of whom two were in complete remission without any treatment during prepregnancy.

The median neonatal birth weight was, respectively, 3272 g (IQR 3028–3539) in LAGB, 3005 g (IQR 2966–3174) in LSG, and 2664 g (IQR 2640–3024) in MS, and a significant difference in neonatal birth weight was noted only between LAGB and MS (Table 4). The rate of emergency cesarean section due to non-reassuring neonatal status was not so different among three types of

Table 3 Maternal weight changes and complications during pregnancy

Types of procedure	LAGB	LSG	MS	*p* value
Number of births (total number = 24)	6	5	13	
Age of delivery[a], years	29 (26–31)	36 (35–37)	32 (30–34)	NS (0.1)[b]
Maximum body weight (during pregnancy)[a], kg	98 (91.5–106)	68.9 (66.0–78.0)	73.5 (66.8–80.9)	<0.01[b]
LAGB vs. LSG				<0.01[c]
LAGB vs. MS				<0.02[c]
LSG vs. MS				NS (0.71)[b]
Weight gain (during pregnancy)[a], kg	12.5 (9.8–20.5)	6.9 (2.3–7.0)	9.0 (8.4–9.3)	<0.02[b]
LSG vs. MS				NS (0.12)[c]
Pregnancy complications (*n*/number of births)				
Maternal anemia (%)*	0/6 (0)	0/5 (0)	9/13 (69)	
Gestational diabetes mellitus (%)**	0/6 (0)	2/5 (40)	0/13 (0)	
Gestational hypertension (%)***	3/6 (50)	1/5 (20)	0/13 (0)	
HELLP syndrome (%)	1/6 (17)	0/5 (0)	0/13 (0)	
Threatened abortion (%)	0/6 (0)	1/5 (20)	1/13 (8)	
Threatened preterm delivery < 37 weeks (%)	0/6 (0)	1/5 (20)	1/13 (8)	

LAGB laparoscopic adjustable gastric banding, *LSG* laparoscopic sleeve gastrectomy, *MS* Roux-en-Y gastric bypass and LSG with duodenojejunal bypass

*Maternal anemia: hemoglobin < 11 g/dl

**Gestational diabetes mellitus: glycosylated hemoglobin (HbA1c) ≥ 6.5%, HELLP; hemolysis, elevated liver enzymes, lowered platelets

***Gestational hypertension: blood pressure systolic > 140 or diastolic > 90 mmHg

[a]Median (IQR)

[b]Kruskal–Wallis test

[c]Multiple comparison (Steel–Dwass)

Table 4 Neonatal birth weight and mode of delivery

Types of procedure	LAGB	LSG	MS	*p* value
Number of births (total number = 24)	6	5	13	
Birth weight[a], g	3272 (3028–3539)	3005 (2966–3174)	2664 (2640–3024)	< 0.04[b]
LAGB vs. LSG				NS (0.40)[c]
LSG vs. MS				NS (0.74)[c]
LAGB vs. MS				< 0.03[c]
Weeks of gestation at delivery	39.6 (38.4–39.4)	39 (39–39.4)	39.3 (38.5–40)	NS (0.78)[b]
Mode of delivery				
Vaginal delivery (%)	4/6 (66)	5/5 (100)	8/13 (62)	
Emergency cesarean section				
Non-reassuring fetal status (%)	1/6 (17)	0/5 (0)	2/13 (15)	
Scheduled cesarean section				
Breech presentation (%)	0/6 (0)	0/5 (0)	2/13 (15)	
History of myomectomy (%)	0/6 (0)	0/5 (0)	1/13 (8)	
History of cesarean (%)	1/6 (17)	0/5 (0)	0/13 (0)	

LAGB laparoscopic adjustable gastric banding, *LSG* laparoscopic sleeve gastrectomy, *MS* Roux-en-Y gastric bypass and LSG with duodenojejunal bypass

[a]Median (IQR)

[b]Kruskal–Wallis test

[c]Multiple Comparison (Steel–Dwass)

surgery. There were no preterm births after any of the surgical procedures.

As described in Table 3, the most frequent pregnancy complication especially in patients who underwent MS was anemia (69%). Table 5 presents the analysis of serum iron and hemoglobin levels during the preoperative and prepregnancy period of all types of surgery. Although the hemoglobin and serum iron level immediately before surgery were similar among the three groups, a significant decrease in hemoglobin (median 1.9 g/dl) and low serum iron (median 38.5 mg/dl) were recognized in patients who underwent MS, and their median hemoglobin level during prepregnancy was the lowest among the three types of surgery. The differences in hemoglobin levels and neonatal birth weights in patients who underwent MS with or without maternal anemia are shown in Table 6. Hemoglobin (median 11.3 g/dl, IQR 10.9–12.0) and serum iron (median 33 mg/dl, IQR 29–39) levels in patients with anemia immediately before pregnancy were lower than those in patients without anemia. Moreover, although there was no significant difference in gestational period in patients with or without maternal anemia, the neonatal birth weight in patients with maternal anemia (median 2660 g, IQR 2640–2868) was relatively lower than that in

patients without maternal anemia (median 3,037 g, IQR 2,914–3,082) and was suggested to be the lowest among all neonates.

Discussion

The important findings in our analysis indicate distinct maternal features depending on the surgical procedure performed.

In our study, the maternal weight and weight gain during pregnancy of patients who underwent LAGB were the highest among the three types of surgery. According to the 2009 guideline from the Institute of Medicine of National Academies, women whose BMI was over 30 kg/m^2 were recommended to have a restriction of 5.0–9.1 kg from the baseline weight during pregnancy for neonatal birth weight control [14]. In Japan, a weight gain of 5–7 kg during pregnancy was also recommended by the Japan Society for the Study of Obesity and Japan Society of Obstetrics and Gynecology to prevent pregnancy and delivery complications in obese women. Although the evidence supporting these weight control guidelines remains insufficient, the maternal weight gain after LAGB was certainly beyond these ranges in our series. Does consistent band adjustment influence

Table 5 Serum iron and hemoglobin at pre-operation and prepregnancy

Types of procedure (number of mothers)	LAGB ($n=6$)	LSG ($n=5$)	MS ($n=13$)	p value
Pre-operation				
Serum iron[a], mg/dl	91.5 (71.3–103.5)	88.0 (74.3–101.8)	85.0 (70.0–92.0)	NS (0.52)[b]
Hemoglobin[a], g/dl	13.6 (13.0–14.1)	13.4 (12.7–13.5)	13.7 (13.1–14.3)	NS (0.67)[b]
Prepregnancy Serum iron[a], mg/dl	72.0 (69.0 –76.5)	113.0 (92.0–135.0)	38.5 (27.5–82.0)	<0.02[b]
Hemoglobin[a], g/dl	13.7 (13.3–14.3)	12.8 (12.1–13.5)	11.5 (11.1–13.0)	<0.05[b]
Decrease of hemoglobin[a], g/dl	0.25 (– 0.8–0.3)	0.6 (0.1–0.6)	1.9 (0.95–3.3)	<0.01[b]

LAGB; laparoscopic adjustable gastric banding, LSG; laparoscopic sleeve gastrectomy, MS; Roux-en-Y gastric bypass and LSG with duodenojejunal bypass,

[a]Median (IQR)

[b]Kruskal–Wallis test

Table 6 The relationship between hemoglobin and neonatal birth weight after MS Maternal anemia vs. Non-maternal anemia

Number of births (n)	Maternal anemia ($n=9$)	Non-maternal anemia ($n=4$)	p value
Hemoglobin[a], g/dl	11.3 (10.9–12.0)	12.0 (11.4–12.7)	NS (0.55)*
Decrease of hemoglobin[a], g/dl	2.0 (0.9–3.2)	1.1 (1.0–1.4)	NS (0.27)*
Serum iron[a], mg/dl	33 (29–39)	89 (84–126)	NS (0.07)*
Weeks of gestation at delivery[a]	39.3 (38.5–39.5)	38.2 (38.3–40.1)	NS (0.99)*
Fetal birth weight[a], g	2660 (2640–2868)	3037 (2914–3082)	NS (0.56)*

MS Roux-en-Y gastric bypass and LSG with duodenojejunal bypass

*Determined via median test

[a]Median (IQR)

poor weight control during pregnancy? Should the band be completely loosened or not? Jeffrey et al. [15] state in the American Society for Metabolic and Bariatric Surgery (ASMBS) recommendations that patients who become pregnant should have band adjustment as necessary for appropriate weight gain to support neonatal growth. Carelli et al. showed that patients who had never had their band adjusted during pregnancy had an average weight gain of 10.6 kg, whereas patients whose band was fully deflated had an average weight gain of 14.1 kg. However, there were no differences between their study and the national statistics in terms of the rate of low or very low birth weight neonates (average 3268 g vs. 3298 g) [16]. Skull et al. [17] also reported that 49 pregnant patients who underwent LAGB and had their band adjusted had a significantly less weight gain compared with those who underwent non-LAGB surgery (3.7 kg vs. 15.6 kg), but their neonatal birth weight was not statistically different (3310 g vs. 3530 g). In our study, one of six patients had delivered with the band kept tight and her predelivery weight gain was only 1.7 kg. In another patient, the banding was completely loosened during early pregnancy and re-tightened by the 33rd week, but the banding was completely re-loosened and her maximum weight gain was 9 kg during predelivery. The bands in the other four patients were completely loosened by the 24th week of pregnancy, and their median weight gain was 18 kg (range 13–30 kg). According to these reports and our results, we suppose that completely loosening the banding certainly must have significantly influenced the excessive maternal weight gain, and thus, keeping the banding was necessary for appropriate maternal weight control. Heude et al. [18] previously reported that high BMI during prepregnancy and weight gain during pregnancy were strongly related to the risk of gestational hypertension. In our study, the mean weight gain in patients with gestational hypertension after LAGB was 14.7 kg (range 9–23 kg), and this must have been undesirable for patients with a BMI of > 30 kg/m^2. Moreover, the mean prepregnancy BMI of patients diagnosed with gestational hypertension was 35.4 kg/m^2, which was relatively higher than that of patients without gestational hypertension (31.2 kg/m^2). Therefore, both high BMI and excessive weight gain during pregnancy must have influenced the gestational blood pressure, thereby necessitating modification of the banding, such as loosening only in symptomatic patients.

According to our study, we should recognize the importance of a decrease in hemoglobin, particularly among patients who undergo MS. The mechanisms of anemia are commonly known, which has been attributed to iron, vitamin B12, and folate deficiency in almost all patients undergoing bariatric surgery. Therefore, routine supplementation to prevent elemental deficiencies has been recommended in the guidelines of the American Association of Clinical Endocrinologists, The Obesity Society, and ASMBS. According

to the guidelines, the total elemental iron supplemented should be 45–60 mg via multivitamins for patients who undergo bariatric surgery as compared with the recommended individual intake of 10–18 mg per day especially for adult women. However, there has been some controversy concerning the rate of anemia after LRYGB over the various reported follow-up periods; therefore, the frequency and related micronutrient deficiencies are highly variable [19]. The specific difficulty in recovering from anemia caused by iron deficiency after MS has been commonly acknowledged to be due to the lack of an acidic environment, reducing the absorptive surface of the duodenum and proximal jejunum. Vargas-Ruiz et al. [20] found that the rates of iron deficiency and vitamin B12 deficiency were 54.5% and 27.2%, respectively, at 3 years after surgery in patients who underwent LRYGB with routine supplementation consisting of 18 mg of iron, 6 mg of vitamin B12, and 400 μg of folic acid. On the other hand, Del Villar Mardrigal et al. [21] also reported that the anemia rate was only 4% in patients who underwent LRYGB, with iron deficiency alone at 2.4% and iron deficiency combined with low vitamin B12 at under 1% only in women who received supplementation exceeding the recommended amounts: elemental iron 98.35 mg/day, vitamin B12 1 mg/day, and folic acid 400 μg/day. However, the percentage of patients with iron deficiency who did not develop anemia was 11%. At our center, the iron supplementation dosage was obviously low compared to the guidelines and previously published reports. However, the cases of maternal anemia post-LSG and post-LAGB were few in our series. Therefore, we presume that the dosage used at our center was adequate for patients who underwent restrictive surgery, but insufficient for those who underwent MS, especially reproductive-aged women. Consequently, we should consider the specific recommendation of additional supplementation or medical prescription especially for reproductive-aged women after MS.

Maternal anemia is known as one of the main causes of low birth weight [22]. In our study, none of the mothers who underwent LAGB and LSG subsequently developed maternal anemia, and the birth weight of their neonates were appropriate for their gestational age. Therefore, we focused on the relationship between maternal anemia and neonatal birth weight in patients who underwent MS and investigated their hemoglobin levels in the prepregnancy stage and their neonatal birth weight. In our study, though the period of gestation at delivery were similar in mothers with or without maternal anemia, the neonatal birth weight in patients with anemia was extremely lower than that in those without anemia, but this difference was not statistically significant due to the small number of patients who underwent MS. Maternal anemia is generally caused by low hemoglobin levels in early pregnancy and the greater expansion of plasma volume compared with the increase in red cell volume in late

pregnancy. Haider et al. [23] also showed in a meta-analysis that the neonates who were born from mothers with anemia in the first or second trimester have higher risks of low birth weight, and an improvement in prenatal mean hemoglobin significantly increased their neonatal birth weight. Based on these findings, we believe that MS lead to malabsorption of oral supplements leading to worsening of the maternal anemia and, subsequently, relatively lower fetal birth weights. Therefore, we can generate a hypothesis that the gestational anemia in patients who underwent MS is one of the causes of low birth weight. From these results, we believe that the statistical relationship between anemia as a side effect of MS and neonatal low birth weight should be evaluated in the future using a multivariate analysis in a large number of patients who underwent MS. The findings may contribute to the development of a solution to the problem of low birth weight after bariatric surgery.

As an unexpected result, two patients who underwent LSG developed gestational diabetes mellitus. Their weight gain during pregnancy were 6.9 kg and 7.2 kg, which is regarded as an appropriate weight gain during the pregnancy period, and they were never diagnosed with type 2 diabetes mellitus during the preoperative period. Therefore, the specific cause of gestational diabetes mellitus after LSG was unclear in our study.

With regard to the difference in the mode of delivery, especially in emergency cesarean section, there were no relations with either the maternal condition or the type of bariatric surgery. Furthermore, there were no elective cesarean sections due to maternal obesity, even in patients with a relatively high BMI who underwent LAGB. In previous reports, statistical relationships between a shorter gestation period or preterm birth and bariatric surgery were noted, but the causes remained unclear in this study. Therefore, a detailed large-scale investigation on the maternal conditions after bariatric surgery may lead to significant findings.

Strengths and limitations of the study

The main strength of our study was its novelty, focusing on the maternal impacts related to neonatal growth and delivery analyzed according to the types of surgery. Bariatric surgery is currently considered the most effective treatment for morbid obesity, and various procedures are performed worldwide. However, the main concepts underlying bariatric surgery are based on the restriction and malabsorption of caloric intake, and the awareness of maternal treatment according to the type of restrictive surgery or MS is important. On the other hand, the main limitation of this study was its small sample size. Therefore, we could only mention the possibility of relationships between maternal anemia after MS and neonatal low birth weight. Moreover, considering

our preliminary outcomes, future large-scale research is required to explore the causes of gestational diabetes mellitus development in patients who underwent LSG.

Conclusion

Not all bariatric procedures might lead to lower fetal birth weight. In particular, the birth weights of neonates born from mothers who had undergone restrictive bariatric were not decreased. The patients who underwent MS tended to be anemic mainly due to iron deficiency caused by taking only the standard dosage of iron supplements recommended for adult women; consequently, this appears to decrease the neonatal birth weight. Therefore, the nutritional status of the pregnant patients should be closely monitored, and the proper collaboration between the bariatric team and obstetricians will result in the effective management of maternal and neonatal health. Moreover, the causes of small for gestational age neonates after bariatric surgery may be determined by investigating the maternal characteristics and complications according to the types of surgery with a large patient cohort.

Compliance with ethical standards

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