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Comparison of pregnancy outcomes after bariatric surgery by sleeve gastrectomy versus gastric bypass

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ABSTRACT

Objective: Bariatric surgery has an impact on subsequent pregnancies, in particular an association between gastric bypass and small for gestational age. Knowledge is lacking on whether sleeve gastrectomy is associated with more favorable pregnancy outcomes. This study aimed to compare the impact of sleeve gastrectomy and Roux-en-Y gastric bypass on the incidence of small for gestational age (SGA), and of adverse pregnancy outcomes.
Study design: We conducted a retrospective study in a single reference center, including all patients with a history of sleeve or bypass who delivered between 2004 and 2021 after their first pregnancy following bariatric surgery. We compared the incidence of SGA, intrauterine growth retardation, preterm delivery and adverse maternal outcomes between patients who had sleeve versus bypass.
Results: Of 244 patients, 145 had a sleeve and 99 had a bypass. The proportion of SGA $<$ 10th percentile did not differ between the two groups (38/145 (26.2 %) vs 22/99 (22.22 %), respectively, $p = 0.48$). Preterm birth $<$ 37 WG was lower in the sleeve group (5/145 (3.45%) vs 12/99 (12.12 %) in the bypass group ($p = 0.01$), as well as NICU hospitalizations (3 (2.07%) vs 12/99 (12.12%), $p < 0.01$). There was no difference regarding adverse maternal outcomes such as gestational diabetes and hypertensive complications. The proportion of SGA was not lower in patients with bypass when adjusting for other risk factors (BMI, smoking, geographic origin, diabetes and hypertension) (aOR 0.70; 95%CI 0.01 – 2.85).
Conclusion: sleeve was associated with an incidence of SGA which was as high as after bypass, however the incidence of preterm birth was lower.

1. Introduction

The prevalence of obesity, defined by the WHO as a body mass index (BMI) greater than or equal to 30, tripled between 1975 and 2016 [1]. In France, obesity concerned 17% of the adult population and 10% of pregnant women in 2016 [2]. It is a risk factor for a number of disorders, including cardiovascular diseases and type 2 diabetes. During pregnancy, it increases the risk of gestational diabetes, pregnancy-induced hypertension, prolonged labor, instrumental or cesarean delivery and shoulder dystocia [3,4], macrosomia and congenital anomalies [5]. Children exposed to maternal obesity in utero are at increased risk of obesity and metabolic syndrome later in life [6].

Bariatric surgery is the reference treatment in cases of severe obesity, allowing significant weight loss and reducing cardiovascular complications [7,8]. The number of procedures increased 20-fold over the past 20 years [9]. There are restrictive (gastric banding, sleeve gastrectomy) and/or malabsorptive (gastric bypass, biliopancreatic diversion) procedures [10]. Sleeve gastrectomy has become over recent years the most practiced bariatric surgery in France, accounting for 58% of procedures in 2016, compared to 25% bypass [9].

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Today, over 80% of bariatric surgery is in women [9] thus impacting pregnancies. Bariatric surgery reduces the risk of gestational diabetes, pregnancy-induced hypertension and fetal macrosomia [11–14] but it can lead to surgical complications during pregnancy [14,15] and an increased risk of small for gestational age (SGA) and intrauterine growth restriction (IUGR) [11–14]. SGA is defined by a birthweight below the 10th percentile, severe when below the 3rd percentile and IUGR in case of arrested growth [16].

Several studies and meta-analyses report an increased risk of SGA/ IUGR in patients with bariatric surgery [11,17,18]. Fewer studies compared the impact of different types of bariatric surgery on neonatal outcomes [3,8,10,19,20], in particular following sleeve gastrectomy. Our objective was to compare the prevalence of SGA between patients with Roux-en-Y gastric bypass versus sleeve gastrectomy. Secondary objectives were to compare pregnancy outcomes according to the type of bariatric surgery.

2. Material and methods

2.1. Study design

We conducted a monocentric retrospective study at the Louis-Mourier University Hospital Center, covering the period from 2004 to 2021. This hospital includes a maternity ward, a digestive surgery department specialized in bariatric surgery and a nutrition department specialized in the management of severe obesity.

2.2. Study population

Data was collected using Orbis and DiammG software. We extracted records from patients with their informed consent between January 2004 and December 2021, including patients from two previous studies [3,19]. We collected demographic, clinical, biological and ultrasound data.

This study concerned all patients with a history of sleeve gastrectomy and/or bypass who gave birth for the first time after the surgery at the Louis-Mourier University Hospital. Live births and fetal deaths in utero were included. We excluded subsequent pregnancies following bariatric surgery, gastric band procedures, deliveries in another center, multiple pregnancies, terminations of pregnancy, miscarriages.

We formed two groups, sleeve gastrectomy and Roux-en-Y gastric bypass patients.

2.3. Endpoints

The primary endpoint was the prevalence of SGA fetuses according to the type of bariatric surgery. SGA was defined by birthweight below 10th percentile. Z-score for birthweight is established by taking into account gestational age at birth and gender. Secondary endpoints were obstetrical (gestational diabetes, gestational hypertension, preeclampsia, preterm delivery) and neonatal (birth data, hospitalization in neonatology, neonatal complications).

2.4. Statistical analyses

Quantitative variables were described using means with standard deviation and medians with interquartile range, and compared using Wilcoxon's or Student's t tests. Categorical variables were described in numbers and percentages and compared using a Chi-square test or Fisher's exact test.

We assessed an association between SGA and the type of bariatric surgery. We performed a univariate analysis, then a multivariate logistic regression using the factors associated in the literature with the risk of SGA fetuses and the variables found to be potentially confounding in univariate analysis [3,16].

Analyses were performed with STATA 16 software.

This study was approved by the French Research Ethics Committee in Obstetrics and Gynecology (study #2023-OBS-0401) [21].

3. Results

3.1. Population description

Among pregnancies followed in our maternity center between January 2004 and December 2021, there were 435 with a history of bariatric surgery (Fig. 1). 191 patients were excluded. 130 of them had an exclusion criterion (including 51 with gastric banding) and 61 had missing information. 244 patients were included, including 89 from two previous studies [3,19], 145 patients in the sleeve group and 99 in the bypass group (of which 2 patients had a sleeve converted to a bypass). 17 were initially gastric band patients (11 in the sleeve group, 6 in the bypass group).

The characteristics of the patients are presented in Table 1. They were comparable in terms of co-morbidities. Patients in the bypass group had a significantly higher mean BMI before surgery and a significantly greater mean weight loss after surgery. The mean time from surgery to the start of pregnancy was significantly shorter in the sleeve group. In contrast, mean weight and BMI at the beginning of pregnancy were similar. Fig. 1.

3.2. Obstetrical management

Obstetrical data are presented in Table 2. Weight gain during pregnancy was greater in patients in the sleeve group. One half of the

Table 1
Baseline maternal characteristics in sleeve gastrectomy and bypass groups.

	Sleeve (N = 145)	Bypass (N = 99)	p
Geographic origin *(n,%)*			0.64
Europe	51 (35.17)	37 (37.37)	
North Africa	54 (37.24)	32 (32.32)	
Sub-Saharan Africa/ Caribbean	34 (23.45)	28 (28.28)	
Other	6 (4.14)	2 (2.02)	
Occupation *(n,%)*			0.09
Self-employed or manager	19 (13.10)	12 (12.12)	
Intermediate professions	35 (24.14)	28 (28.28)	
Employee, worker	51 (35.17)	37 (37.37)	
Unemployed	39 (26.90)	21 (21.21)	
Missing data	1 (0.69)	1 (1.01)	
Smoking *(n,%)*	13 (8.97)	9 (9.18)	0.95
Medical history *(n,%)*			
Pregestational Hypertension	9 (6.21)	8 (8.08)	0.61
Pregestational Diabetes	8 (5.52)	2 (2.02)	0.21
Other *	29 (20)	21 (21.21)	0.82
Surgical history *(n,%)*	53 (36.55)	33 (33.33)	0.61
BMI before bariatric surgery *(mean, IQR)*	43.5 (39.8 – 46.2)	46.5 (42.2 – 51.2)	< **0.01**
Weight loss following surgery *(kg) (mean, IQR)*	35.4 (25.5 – 44)	43 (35–52)	< **0.01**
Time between surgery and conception (months) *(mean, IQR)*	33.7 (12–48)	40.9 (22–60)	**0.02**
Maternal age *(mean, IQR)*	32.1 (29–36)	32.3 (29–36)	0.61
Maternal weight at conception (kg) *(mean, IQR)*	83.5 (72–92)	86.5 (71.6 – 96)	0.30
BMI at conception kg/m^2 *(mean, IQR)*	30.4 (27–34)	31.1 (26.5 – 35)	0.64
Nulliparity *(n,%)*	69 (47.59)	45 (45.45)	0.74
Pregnancies obtained after infertility treatment *(n,%)*	5 (3.47)	2 (2.02)	0.70

BMI: body mass index.
IQR: interquartile range.
*Other medical history: asthma, dysthyroidism, lithiasis (hepatic or renal), endometriosis, psychiatric disorder, Crohn's disease, veinous thromboembolic disease.
Qualitative data are expressed in number, %. Quantitative data are expressed as mean, IQR.

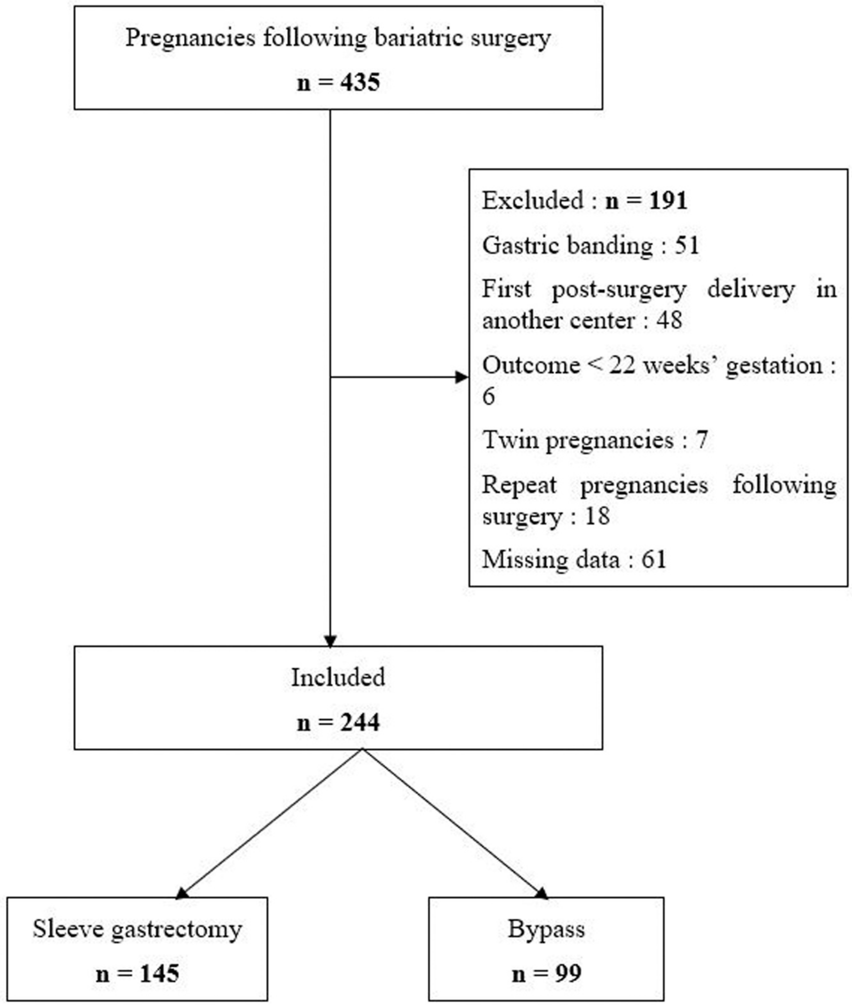

Fig. 1. Flowchart.

patients (50.8%) were seen in a nutrition day hospital. The occurrence of gestational diabetes (20 sleeve vs 21 bypass patients, $p = 0.38$) or hypertensive disorders of pregnancy was not significantly different between the two groups. There were more fetuses followed for SGA or IUGR in the sleeve group but the difference was not statistically significant. It should be noted that only patients followed in recent years had a systematic ultrasound to monitor fetal growth between 35 and 37 WG (81 sleeve patients, 37 bypass patients), and the fetal growth was not significantly different. There was no case of absent or reversed end-diastolic Doppler flow among the SGA/IUGR cases.

There were 49 inductions of labor among sleeve patients versus 23 among bypass patients, which was not significantly different. The modes of delivery were similar in both groups. bypass patients gave birth at a significantly earlier mean gestational age and there was a significantly higher incidence of preterm birth. Regarding preterm birth in the sleeve group, it was related to IUGR ($n = 2$) and premature rupture of membranes ($n = 3$, two inductions at 36WG, one cesarean section for labor in a patient with three prior cesareans). In the bypass group, it was related to IUGR ($n = 1$), fetal heart rhythm abnormalities ($n = 2$), premature rupture of membranes ($n = 8$) and one case of a post-bypass complication (acute intestinal intussusception with suspected perforation).

The average length of stay in the post-partum period was significantly longer for bypass patients.

3.3. Neonatal data

Neonatal data are presented in Table 3. The mean birth weight was 3154.4 g in the sleeve group versus 3016.8 g in the bypass group ($p = 0.06$). The mean raw Z-score was -0.58 in the sleeve group, compared to -0.49 in the bypass group ($p = 0.67$). There was no significant difference in birthweight and Z-score. In the sleeve group, 28 fetuses were below the 10th percentile (26.2%) vs 22 (22.22%, $p = 0.48$) in the bypass group, which was not significatively different.

There were more neonatal care hospitalizations in the bypass group. In the sleeve group, they were related to neonatal infection and prematurity ($n = 3$). In the bypass group, they were for respiratory distress ($n = 6$), infections ($n = 2$), jaundice ($n = 2$), prematurity ($n = 1$) and management of malformation ($n = 1$, a case of myelomeningocele managed postnatally in another center). There was one neonatal death in the bypass group, following delivery at 41WG + 3 with fetal heart rate abnormalities, early-onset neonatal infection, complicated by hypothermia, seizures and finally death related to an anoxo-ischemic encephalopathy.

To construct our multivariate analysis models we adjusted for the factors shown to be associated with SGA in the literature [3,16]: ethnicity, smoking, BMI at conception, diabetes mellitus, hypertensive disorders (Table 4). The OR associated with bypass was 0.55 (95% CI 0.23 - 1.30) and therefore not significant. The other factors studied also had no significant impact, with the exception of smoking and ethnicity.

Table 2
Pregnancy outcomes following sleeve gastrectomy vs gastric bypass.

	Sleeve (N = 145)	Bypass (N = 99)	p
Weight gain during pregnancy *kg (mean, IQR)*	10.4 (6–14)	7.3 (4–12)	**< 0.01**
Vitamin supplementation *(n,%)*	101 (69.66)	61 (61.62)	0.19
Day hospital nutrition program n *(n,%)*	76 (52.41)	48 (48.48)	0.55
Diabetes mellitus *(n,%)*	24 (16.55)	22 (22.22)	0.27
Gestational, diet only	18 (12.50)	20 (20.20)	
Gestational, insulin	2 (1.39)	1 (1.01)	
Preexisting type 2 diabetes	3 (2.08)	1 (1.01)	
Hypertension *(n,%)*			0.53
Gestational HTN	2 (1.38)	3 (3.09)	
Preeclampsia	5 (3.45)	2 (2.06)	
Ultrasound findings			
Percentile T2 *(mean, IQR)*	53.5 (35–75)	51.3 (40–69)	0.52
Percentile T3 *(mean, IQR)*	45.8 (20–62)	47.4 (25–69)	0.71
Ultrasound SGA / FGR *(n,%)*	12 (8.82)	5 (6.17)	0.61
Doppler anomalies *(n,%)*	1 (0.73)	2 (2.5)	0.56
Labor induction *(n,%)%*	49 (33.79)	23 (23.23)	0.08
Mode of delivery *(n,%)*			0.55
Vaginal, spontaneous	92 (63.45)	62 (62.63)	
Vaginal, instrumental	13 (8.97)	13 (13.13)	
Cesarean section	40 (27.59)	24 (24.24)	
Shoulder dystocia	2 (1.90)	2 (2.67)	0.70
Gestational age at birth, WG *(mean, IQR)*	39 + 5 (38 +6 – 40 +4)	38 + 6 (38 +1 – 40 +3)	**< 0.01**
Preterm birth < 37 WG *(n,%)*	5 (3.45)	12 (12.12)	**0.01**
Preterm birth < 34 WG *(n,%)*	0	5 (5.05)	**0.01**
Maternal Complications *(n,%)*			
Post partum hemorrhage	9 (6.21)	4 (4.04)	0.57
Post-partum thrombosis or embolism	0	0	
Obstetrical anal sphincter injury (OASI)	0	0	
Duration of postpartum hospitalization, days *(mean, IQR)*	5.0 (4–5)	6.1 (4–6)	**< 0.01**

HTN: arterial hypertension, T2: 2nd trimester, T3: 3rd trimester, SGA: small for gestational age, FGR: fetal growth restriction. WG: weeks' gestation
Qualitative data are expressed in number, %. Quantitative data are expressed as mean, IQR.

Table 3
Neonatal outcomes.

	Sleeve (n = 145)	Bypass (n = 99)	p
Sex *(n,%)*			0.47
Female	68 (46.9)	45 (45.45)	
Male	77 (53.1)	54 (54.55)	
Birthweight *(mean, IQR)*	3154.4 (2865 – 3460)	3016.8 (2720 – 3460)	0.06
Z-score *(mean, IQR)*			
Crude birthweight Z-score	-0.55 (−1.30 – 0.06)	-0.49 (−1.21- 0.22)	0.66
Cumulative proportion < 10th percentile	38 (26.2)	22 (22.22)	0.48
Proportion < 3rd percentile	12 (8.28)	7 (7.07)	0.73
Apgar score at 5 min			
Mean *(mean, IQR)*	9.9 (10–10)	9.6 (10–10)	**0.04**
Apgar < 7 *(n,%)*	1 (0.69)	4 (4.04)	
Arterial cord pH			
Mean *(mean, IQR)*	7.27 (7.22 – 7.32)	7.27 (7.21 – 7.33)	0.94
pH ≤ 7.20 *(n,%)*	29 (20.57)	18 (22.78)	0.70
NICU hospitalization *(n,%)*	3 (2.07)	12 (12.12)	**0.01**
Neonatal complications *(n,%)*			
Malformations	0	1 (1.01)	0.41
Shoulder dystocia	2 (1.38)	2 (2.02)	0.70

NCIU = neonatal intensive care
Qualitative data are expressed in number, %. Quantitative data are expressed as mean, IQR.

Table 4
Type of bariatric surgery and other risk factors for small for gestational age (Z-score < 10th percentile).

	SGA (n = 60)	**Not SGA (n = 184)**	**Univariate analysis OR** (95%CI)	**Multivariate analysis aOR** (95%CI)
Geographic origin *(n, %)*				
Europe	16 (26.7)	72 (39.1)	Reference	Reference
North Africa	20 (33.3)	66 (35.9)	1.36 (0.65 – 2.85)	1.26 (0.59 – 2.68)
Sub-Saharan Africa or Caribbean	22 (36.7)	40 (21.7)	2.48 (1.17 – 5.25)	2.69 (1.25 – 5.84)
Other	2 (3.3)	6 (3.3)	1.5 (0.28 – 8.13)	1.38 (0.25 – 7.72)
Smoking *(n, %)*	9 (15)	13 (7.1)	2.31 (0.93 – 5.71)	2.60 (1.01 – 6.68)
BMI at conception *(mean, IQR)*	30.5 (27–34)	30.2 (27–34)	0.99 (0.94 – 1.05)	1.00 (0.94 – 1.06)
Diabetes mellitus *(n, %)*	15 (25)	31 (16.9)	1.65 (0.82 – 3.31)	1.77 (0.84 – 3.73)
Hypertension *(n, %)*	2 (3.3)	10 (5.4)	0.83 (0.22 – 3.07)	0.65 (0.17 – 2.57)
Gastric bypass *(n, %)*	22 (36.7)	77 (41.8)	0.80 (0.44 – 1.47)	0.75 (0.04 – 1.40)

SGA: small for gestational age, BMI: body mass index, OR: odds ratio. aOR: adjusted odds ratio.
Hypertension: includes pregestational hypertension, gestational hypertension and preeclampsia.
Qualitative data are expressed in number, %. Quantitative data are expressed as mean, IQR.

4. Discussion

We observed a high incidence of SGA following bariatric surgery, 26% in case of sleeve gastrectomy, which was not lower than in case of gastric bypass (22%). These numbers are higher than those of the general French population (11.0% in 2021) [2]. The only factors with a significant impact on SGA were ethnicity and smoking during the pregnancy.

Many published studies demonstrated an increased risk of SGA in malabsorptive surgery [12,13], up to threefold in the case of malabsorptive surgery when compared with controls [11,17]. Studies comparing bypass and gastric banding found a higher incidence of SGA in case of gastric bypass [10,22]. In a study on 139 patients from our center, published in 2016 [3], the incidence of SGA was twofold higher in patients who had a malabsorptive procedure in comparison with purely restrictive surgery, including only 9 cases of sleeve (29% vs. 9% respectively, 6% in the control group matched on pre-pregnancy BMI).

Few studies suggested an increased risk of SGA in patients who have undergone sleeve [23,24]. One study found significantly more SGA in sleeve patients, in comparison with a control group (14.3% vs 4.2%, p = 0.01) [23].

There are few previous studies specifically comparing the impact of sleeve on SGA, compared to gastric bypass [14,20,25,26]. In a previous study from our center by [19] including patients with a history of bypass (n = 77) and sleeve (n = 46), the occurrence of SGA regardless was 24% and 19% respectively, p = 0.72, similarly to the present study. Cornthwaite et al. [10] compared sleeve (n = 29) and bypass (n = 134), and found no significant difference in birth weight (3159 g vs 3199 g, p = 0.44) or small for gestational age (11% vs 3%, p = 0.26). A recent large retrospective study in the French national medical expenditure database [27] showed an incidence of SGA which was nearly threefold higher after bariatric surgery compared to the pregnancy before bariatric surgery in the same women (28.2% bypass, 71.8% sleeve), and also found an incidence of SGA above 15% following sleeve as well as bypass. There was no difference according to the type of bariatric surgery. In a meta-analysis by Mustafa et al. [8] comparing obstetric and neonatal outcomes in patients who had gastric bypass (n = 5194) or sleeve (n = 405), two studies specifically compared sleeve and gastric bypass. There was no difference in SGA incidence (OR 0.88, 95% CI −1.33 - 9.61) and maternal complications (gestational diabetes, hypertensive complications). A systematic review from 2023 [28] also highlighted the occurrence of SGA whatever the type of bariatric surgery, but more significantly in the case of sleeve.

Gastric bypass leads to vitamin deficiencies requiring lifelong supplementation, as well as dumping syndrome and post-dumping syndrome (hypoglycemia away from meals). sleeve, retaining part of the stomach, is associated with fewer vitamin deficiencies [29,30]. If sleeve is associated with SGA [23] this might suggest that it is not purely restrictive. The impact of bariatric surgery on nutritional balance is well described [12,14,31]. In a study from our center [19] vitamin deficiencies were present in both types of bariatric surgery, with a similar number of deficiencies but different deficiencies according to the type of surgery. In our study, 66.4% of patients received vitamin supplementation and one half had at least one consultation with a team specialized in nutrition during their pregnancy. The proportion of patients receiving supplements increased over time, in accordance with the policy we established in 2010 offering a day-hospitalization session to all pregnant women with a history of bariatric surgery. Nearly one half of the patients did not receive the recommended nutritional evaluation and prescriptions for nutritional supplements, either because they had been operated outside our center or because they did not attend the recommended visits. We cannot estimate how many of these patients took nutritional supplements without a prescription by the specialized team. However, we found no significant difference in univariate analysis according to vitamin prescription. Only one sleeve technique exists, while there are several bypass techniques. The technique used in our center, as in other centers in Paris, is bypass.

Several studies have shown a reduction in the incidence of the occurrence of pregnancy-induced hypertension, preeclampsia and diabetes after bariatric surgery [11,32]. In our cohort, preeclampsia was slightly more frequent in the sleeve group than in the bypass group, and only one case was associated with SGA, remaining consistent with the general French population [2]. The incidence of gestational diabetes was higher in both of our groups than in the general French population (4.7% gestational diabetes on insulin, 11.4% gestational diabetes on diet in 2021) [2] and higher than in previous studies on bariatric patients [11, 12]. The diagnostic method may have influenced this rate. Glucose challenge tests can be performed only in patients who have had a sleeve. For bypass patients, it is replaced by fasting and postprandial blood sugar determinations, which are known to underestimate the diagnosis of gestational diabetes.

We found significantly more preterm deliveries (12.12%), more hospitalizations in neonatology (12.12%) and a longer length of postpartum hospitalization in the bypass group. The higher rate of prematurity could account for the other outcomes. These numbers are slightly higher than those of the general French population (7.0 % in 2021) [2]. The incidence of preterm delivery following bariatric surgery was 8 % in the study by Cornthwaite [10] and 8.6% in Chevrot [3], which is in line with those of several meta-analyses [12,13,33], and cohorts [14,34], while the recent study by Rives-Lange [27] found a prematurity rate close to that of the French population after bariatric surgery (7.6% vs. 6.3% before surgery). In contrast, the cohort of 135 patients published by White in 2023 [35] showed 26% prematurity.

The strengths of our study are the large cohort and the exhaustive follow-up done on the same site for both obstetrical and nutritional aspects. A large proportion of sleeve surgery patients is included, reflecting current bariatric surgery practices. One limitation of our study is inherent to an observational study, since the two groups of patients were not exactly in the absence of randomization. Many files were excluded due to lacking data, in order to avoid potential biases. Despite our large cohort, there were 60 cases of SGA which may not provide sufficient power to identify some factors other than smoking which may be associated with SGA.

Sleeve gastrectomy is a risk factor for obstetrical outcomes. Bariatric surgery requires specialized nutritional monitoring and careful obstetrical care, following the published recommendations concerning the obstetric follow-up of these high-risk pregnancies and focusing on monitoring fetal growth in the third trimester of pregnancy in order to detect SGA/IUGR [36]. However, we found an incidence of SGA at birth which was higher than diagnosed by prenatal ultrasound, despite the practice of third trimester ultrasound which is recommended for all pregnancies in France, and our systematic practice of performing an additional ultrasound around 8 months of pregnancy for fetal growth in patients who had bariatric surgery. One hypothesis would be that the onset of growth restriction in bariatric surgery pregnancies can be in advanced gestation.

In the absence of a randomized trial, these data should be confirmed on a larger population, allowing adjustment on a propensity score. It would also be interesting to compare the long-term evolution of children. Studies have already been published concerning the future of these children suggesting an increased risk of cardiovascular disorders and obesity [6,37].

5. Conclusion

Sleeve gastrectomy was associated with a high incidence of SGA, which contrary to our expectations was not lower than following bypass surgery. However, the incidence of preterm birth was lower in SG, compared to bypass patients. Thus, although leading to less malabsorption than gastric bypass, sleeve remains a risk factor requiring careful monitoring of maternal nutritional status and fetal growth.

CRediT authorship contribution statement

Marie-Anne Joly: Writing – review & editing, Writing – original draft, Validation,Data curation, Conceptualization. **Violaine Peyronnet:** Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Muriel Coupaye:** Validation, Data curation. **Séverine Ledoux:** Validation. **Nicolas Pourtier:** Validation. **Lucile Pencole:** Validation, Supervision, Conceptualization. Laurent Mandelbrot: Writing – review & editing, Validation, Supervision, Methodology, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Neylan CJ, Kannan U, Dempsey DT, Williams NN, Dumon KR. The surgical management of obesity. Gastroenterol Clin North Am déc 2016;45(4):689–703.
[2] Enquête nationale périnatale. Rapport 2021. Les naissances, le suivi à deux mois et les établissements [Internet]. [cité 6 juin 2023]. Disponible sur: https://www.santepubliquefrance.fr/import/enquete-nationale-perinatale.-rapport-2021.-les-naissances-le-suivi-a-deux-mois-et-les-etablissements.
[3] Chevrot A, Kayem G, Coupaye M, Lesage N, Msika S, Mandelbrot L. Impact of bariatric surgery on fetal growth restriction: experience of a perinatal and bariatric surgery center. Am J Obstet Gynecol mai 2016;214(5). 655.e1-7.
[4] Weiss JL, Malone FD, Emig D, Ball RH, Nyberg DA, Comstock CH, et al. Obesity, obstetric complications and cesarean delivery rate–a population-based screening study. (avr) Am J Obstet Gynecol 2004;190(4):1091–10910.
[5] Blomberg MI, Källén B. Maternal obesity and morbid obesity: the risk for birth defects in the offspring (janv) Birt Defects Res A Clin Mol Teratol 2010;88(1):35–40.
[6] Boney CM, Verma A, Tucker R, Vohr BR. Metabolic syndrome in childhood: association with birth weight, maternal obesity, and gestational diabetes mellitus. Pediatrics 2005;115(3):e290–6.
[7] Sjöström L, Peltonen M, Jacobson P, Sjöström CD, Karason K, Wedel H, et al. Bariatric surgery and long-term cardiovascular events. 4 janv JAMA 2012;307(1):56–65.
[8] Mustafa HJ, Javinani A, Seif K, Aghajani F, Makar EJ, Selhorst S, et al. Prepregnancy Roux-en-Y gastric bypass vs sleeve gastrectomy: a systematic review,

pairwise, and network meta-analysis of obstetrical and neonatal outcomes (juin) Am J Obstet Gynecol MFM 2023;5(6):100914.

[9] Direction de la recherche, des études, de l'évaluation et des statistiques. Chirurgie de l'obésité: 20 fois plus d'interventions depuis 1997 [Internet]. Etudes & Résultats; 2018. Disponible: https://drees.solidarites-sante.gouv.fr [Internet]. [cité 6 juin 2023]. Disponible sur: https://drees.solidarites-sante.gouv.fr/publications/etudes-et-resultats/chirurgie-de-lobesite-20-fois-plus-dinterventions-depuis-1997.

[10] Cornthwaite K, Prajapati C, Lenguerrand E, Knight M, Blencowe N, Johnson A, et al. Pregnancy outcomes following different types of bariatric surgery: A national cohort study (mai) Eur J Obstet Gynecol Reprod Biol 2021;260:10–7.

[11] Johansson K, Cnattingius S, Näslund I, Roos N, Trolle Lagerros Y, Granath F, et al. Outcomes of pregnancy after bariatric surgery. N Engl J Med 26 févr 2015;372(9):814–24.

[12] Galazis N, Docheva N, Simillis C, Nicolaides KH. Maternal and neonatal outcomes in women undergoing bariatric surgery: a systematic review and meta-analysis. Eur J Obstet Gynecol Reprod Biol oct 2014;181:45–53.

[13] Yi X yan, Li Q fu, Zhang J, Wang Z hong. A meta-analysis of maternal and fetal outcomes of pregnancy after bariatric surgery (juill) Int J Gynaecol Obstet Organ Int Fed Gynaecol Obstet 2015;130(1):3–9.

[14] Falcone V, Stopp T, Feichtinger M, Kiss H, Eppel W, Husslein PW, et al. Pregnancy after bariatric surgery: a narrative literature review and discussion of impact on pregnancy management and outcome. BMC Pregnancy Childbirth déc 2018;18(1):507.

[15] Chevrot A, Lesage N, Msika S, Mandelbrot L. Digestive surgical complications during pregnancy following bariatric surgery: Experience of a center for perinatology and obesity (avr) J Gynecol Obstet Biol Reprod 2016;45(4):372–9.

[16] CNGO, Recommandations pour la pratique clinique. Le retard de croissance intra-utérin; 2013. Disponible: http://www.cngof.asso.fr/data/RCP/CNGOF_2013_FINAL_RPC_rciu.pdf. J Gynécologie Obstétrique Biol Reprod. sept 2005;34(5):513.

[17] Kjær MM, Lauenborg J, Breum BM, Nilas L. The risk of adverse pregnancy outcome after bariatric surgery: a nationwide register-based matched cohort study. Am J Obstet Gynecol juin 2013;208(6). 464.e1-5.

[18] Roos N, Neovius M, Cnattingius S, Trolle Lagerros Y, Sääf M, Granath F, et al. Perinatal outcomes after bariatric surgery: nationwide population based matched cohort study. BMJ nov 2013;12(347):f6460.

[19] Coupaye M, Legardeur H, Sami O, Calabrese D, Mandelbrot L, Ledoux S. Impact of Roux-en-Y gastric bypass and sleeve gastrectomy on fetal growth and relationship with maternal nutritional status. Surg Obes Relat Dis J Am Soc Bariatr Surg oct 2018;14(10):1488–94.

[20] Yu Y, Groth SW. Risk factors of lower birth weight, small-for-gestational-age infants, and preterm birth in pregnancies following bariatric surgery: a scoping review. Arch Gynecol Obstet févr 2023;307(2):343–478.

[21] Dabi Y, Thubert T, Fuchs F, Barjat T, Belaisch-Allart J, Ceccaldi PF, et al. How is functionning the ethical review board " Comité d'Ethique Pour La Recherche En Obstétrique Et Gynécologie " (CEROG) ? (avr) J Gynecol Obstet Hum Reprod 2022;51(4):102352.

[22] Ducarme G, Parisio L, Santulli P, Carbillon L, Mandelbrot L, Luton D. Neonatal outcomes in pregnancies after bariatric surgery: a retrospective multi-centric cohort study in three French referral centers (févr) J. Maternal-Fetal & Neonatal Med. 2013;26(3):275–8.

[23] Rottenstreich A, Elchalal U, Kleinstern G, Beglaibter N, Khalaileh A, Elazary R. Maternal and perinatal outcomes after laparoscopic sleeve gastrectomy (mars) Obstet Gynecol 2018;131(3):451–6.

[24] Chatzistergiou TK, Zervaki DS, Derouich M, Lazzati A. Laparoscopic sleeve gastrectomy and pregnancy outcomes: a systematic review (janv) Eur J Obstet Gynecol Reprod Biol 2021;256:339–47.

[25] Sesilia K, Susanna P, Virve K, Mika G, Veli-Matti U, Marja K. The outcome of pregnancies after bariatric surgery: an observational study of pregnancies during 2004-2016 in Finland (mai) Arch Gynecol Obstet 2023;307(5):1599–606.

[26] Boller MJ, Xu F, Lee C, Sridhar S, Greenberg MB, Hedderson MM. Perinatal outcomes after bariatric surgery compared with a matched control group. 1 mars Obstet Gynecol 2023;141(3):583–91.

[27] Rives-Lange C, Poghosyan T, Phan A, Van Straaten A, Girardeau Y, Nizard J, et al. Risk-benefit balance associated with obstetric, neonatal, and child outcomes after metabolic and bariatric surgery. 1 janv JAMA Surg 2023;158(1):36–44.

[28] Kistner A, Werner A, Zaigham M. Adverse perinatal outcomes after Roux-en-Y Gastric Bypass vs. Sleeve Gastrectomy: a systematic review. BMC Pregnancy Childbirth 2 août 2023;23(1):557.

[29] Coupaye M, Rivière P, Breuil MC, Castel B, Bogard C, Dupré T, et al. Comparison of nutritional status during the first year after sleeve gastrectomy and Roux-en-Y gastric bypass. 1 févr Obes Surg 2014;24(2):276–83.

[30] Coupaye M, Sami O, Calabrese D, Flamant M, Ledoux S. Prevalence and determinants of nutritional deficiencies at mid-term after sleeve gastrectomy (juin) Obes Surg 2020;30(6):2165–72.

[31] Hazart J, Le Guennec D, Accoceberry M, Lemery D, Mulliez A, Farigon N, et al. Maternal nutritional deficiencies and small-for-gestational-age neonates at birth of women who have undergone bariatric surgery. J Pregnancy 2017;2017:4168541.

[32] Johansson K, Wikström AK, Söderling J, Näslund I, Ottosson J, Neovius M, et al. Risk of pre-eclampsia after gastric bypass: a matched cohort study. BJOG Int J Obstet Gynaecol Févr 2022;129(3):461–71.

[33] Akhter Z, Rankin J, Ceulemans D, Ngongalah L, Ackroyd R, Devlieger R, et al. Pregnancy after bariatric surgery and adverse perinatal outcomes: a systematic review and meta-analysis (août) PLoS Med 2019;16(8):e1002866.

[34] Youssefzadeh AC, Klar M, Seifert GJ, Mandelbaum RS, Sangara RN, McCarthy LE, et al. Pregnancy characteristics and outcomes after bariatric surgery: national-level analysis in the United States. Surg Obes Relat Dis J Am Soc Bariatr Surg Avr 2023;19(4):364–473.

[35] White GE, Courcoulas AP, Broskey NT, Rogan SC, Jeyabalan A, King WC. Maternal and neonatal outcomes of pregnancy within 7 years after Roux-Y gastric bypass or sleeve gastrectomy surgery (juin) Obes Surg 2023;33(6):1764–72.

[36] Ciangura C, Coupaye M, Deruelle P, Gascoin G, Calabrese D, Cosson E, et al. Clinical practice guidelines for childbearing female candidates for bariatric surgery, pregnancy, and post-partum management after bariatric surgery. Obes Surg nov 2019;29(11):3722–34.

[37] Van De Maele K, Bogaerts A, De Schepper J, Provyn S, Ceulemans D, Guelinckx I, et al. Adiposity, psychomotor and behaviour outcomes of children born after maternal bariatric surgery (mai) Pedia Obes 2021;16(5):e12749.