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Reproductive outcome after bariatric surgery: a critical review

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BACKGROUND: After many cycles of weight loss and weight gain, more and more morbidly obese patients undergo bariatric surgery, like gastric banding or gastric bypass, as the ultimate treatment for their obesity-problem. Since women of reproductive age are candidates for bariatric surgery, concerns arise regarding the potential impact on future pregnancy.

METHODS: English-language articles were identified in a PUBMED search from 1982 to January 2008 using the keywords for pregnancy and bariatric surgery or gastric bypass or gastric banding.

RESULTS: The few reported case–control and cohort studies clearly show improved fertility and a reduced risk in obstetrical complications, including gestational diabetes, macrosomia and hypertensive disorders of pregnancy, in women after operatively induced weight loss when compared with morbidly obesity women. The incidence of intrauterine growth restriction (IUGR) appears to be increased, however. No conclusions can be drawn concerning the risk for preterm labour and miscarriage, although these risks are probably increased compared with controls matched for body mass index. Operative complications are not uncommon with bariatric surgery and several cases have pointed to the increased risk for intestinal hernias and nutritional deficiencies in subsequent pregnancy. Deficiencies in iron, vitamin A, vitamin B_{12}, vitamin K, folate and calcium can result in both maternal complications, such as severe anaemia, and fetal complications, such as congenital abnormalities, IUGR and failure to thrive.

CONCLUSIONS: Close supervision before, during and after pregnancy following bariatric surgery and nutrient supplementation adapted to the patient's individual requirements can help to prevent nutrition-related complications and improve maternal and fetal health, in this high-risk obstetric population.

Key words: bariatric surgery / pregnancy / nutrition / obesity

Introduction

Putting a brake on the obesity, epidemic has become a priority worldwide. The World Health Organization estimates that 54.3% of the women and 51.7% of the men in the USA will be obese (body mass index (BMI) >30 kg/m^2) in 2015. In the United Kingdom, the prevalence of obesity among women at reproductive age is expected to rise from 24.2% in 2005 to 28.3% in 2015 (Ono *et al*., 2005).

In addition to mechanical and psychological complications, obesity is associated with metabolic complications such as insulin-resistance, type 2 diabetes, dyslipidaemia, hypertension and polycystic ovary syndrome, leading to fertility problems (Ehrmann, 2005). For women of reproductive age, prepregnancy obesity is a risk factor for shortand long-term maternal and fetal complications, including miscarriage, gestational diabetes, pregnancy-induced hypertension (PIH), labour induction, Caesarean section (CS), macrosomia, birth defects, post-partum weight retention and juvenile obesity (Guelinckx *et al*., 2008).

The first targets in obesity treatment are lifestyle changes, including decreased energy intake and increased physical activity levels. Even if these interventions are supported by pharmacotherapy, a sustained weight loss is achieved by just a small part of the population (Karlsson *et al*., 2007). For morbidly obese individuals (BMI $\geq$ 40 kg/m^2) or for those with a BMI $>$ 35 kg/m^2 who have already obesity-related co-morbidities, bariatric surgery in combination with a healthy lifestyle may be a long-term option (Santry *et al*., 2005).

The number of bariatric surgical procedures being performed is increasing significantly in the USA: from 13 365 in 1996 to 72 177 in 2002, especially in women (84% of the patients) (Santry *et al*., 2005). A 5-fold increase was also observed among adolescents, predominantly female patients with a mean age of 16 years (from 51 in 1997 to 282 in 2003) (Schilling *et al*., 2008). As a consequence, more women with a history of prior bariatric surgery will become pregnant, indicating the importance of rigorous scientific investigation into pregnancy outcomes in this population.

Methods

The aim of this review is to briefly describe commonly performed bariatric procedures and to summarize the literature reporting on pregnancy outcome following bariatric surgery. English-language articles were identified by searching PUBMED from 1982 to January 2008 using the keywords 'pregnancy AND bariatric surgery or gastric bypass or gastric banding'. Additional articles were collected by cross-referencing from articles identified by the search.

Bariatric surgery procedures

Procedures for bariatric surgery are traditionally categorized into three groups. The aim of the first group of procedures is to restrict energy intake by reducing gastric capacity. This includes the vertical banded gastroplasty (Mason) and the laparoscopic adjustable gastric band (LAGB). The Roux-en-Y gastric bypass (RYGB) is the second type, which combines food restriction with a certain degree of malabsorption by shortening the length of the intestinal tract. The third group includes the malabsorptive procedures such as the biliopancreatic diversion or Scopinaro procedure (BPD), BPD with duodenal switch and jejuno-ileal bypass. The latter is at present almost completely abandoned due to substantial long-term complications of hepatic failure, calcium oxalate kidney stones, renal failure, arthritis and malnutrition (Livingston, 2002). The most performed procedures today are the LAGB and the RYGB.

For the LAGB, one uses a silicon inflatable gastric band, placed horizontally around the proximal part of the stomach. Through a subcutaneous port, the band is inflated or deflated with fluid creating a small or larger gastric pouch. The idea behind the pouch is to reduce storage capacity, leading to early satiety and reduced caloric intake. The RYGB also starts with the laparoscopic creation of a gastric pouch; however, in this case, the pouch is separated from the remaining stomach by stapling or transection. The gastric pouch empties directly into the distal jejunum through a constructed gastrojejunostomy. This means that the remaining stomach, all of the duodenum and 40–150 cm of the proximal jejunum are bypassed, resulting in reduced absorptive area (Bult *et al*., 2008).

After 15 years follow-up of the Swedish obese subjects (SOS-study), the LAGB and RYGB resulted in a mean weight loss of 13 $\pm$ 14% and 27 $\pm$ 12%, respectively, compared with baseline weight (Sjostrom *et al*., 2007). The immediate and long-term operative mortalities of LAGB and RYGB are $\sim$0.1% and 0.5%, respectively. Complications occur in $\sim$5% of cases with both procedures. Long-term complications associated with LAGB include vomiting, gastric prolapse, stomal obstruction, esophageal and gastric pouch dilatation, gastric erosion and necrosis, and access port problems (Buchwald, 2005). Nutritional deficiencies after LAGB are less common but can occur because of the restricted dietary intake and therefore a limited intake of nutrients. RYGB can be complicated in the long-term by the dumping syndrome, stomal stenosis, marginal ulcers, staple line disruption, internal hernias and nutrient deficiencies including iron, folate, calcium and vitamin B_{12} (Buchwald, 2005; Woodard, 2004). Nutritional deficiencies after RYGB can arise through different mechanisms. First, the induced dietary restriction leads to insufficient intake and an intolerance to certain food articles (meat, milk, fibre) could be induced by the operation, leading to a diet without variation. Second, the inferior part of the stomach is excluded leading to a decreased gastric acid secretion, necessary to absorb vitamins and minerals (vitamin B_{12} and iron). Bypassing the absorption sites for several nutrients is a third mechanism. Asynergia between the bolus and the biliopancreatic secretions in the common part of the small intestine is the last mechanism (Poitou Bernert, 2007). Dumping syndrome can be experienced if patients ingest large quantities of simple carbohydrates. It is important to note that the standard screening test for gestational diabetes, a 50-g glucose challenge test, can also provoke these symptoms (Wax *et al*., 2007a).

Reproductive issues after bariatric surgery

Even though bariatric surgery has been performed since the 1960s, the literature reporting on pregnancy outcome after bariatric surgery is limited and consists only of a few case–control and cohort studies with a number of case reports. Tables I and II summarize the available literature, according to study design. In the next paragraphs, obstetrical outcomes, including miscarriage, birthweight, the incidence of prematurity, gestational weight gain (GWG) and mechanical complications, will be discussed.

Pregnancy complications

Most case–control studies demonstrated increased fertility after bariatric surgery. Obesity is characterized by a state of hyperinsulinism, which may cause hyperandrogenism leading to amenorrhoea and endocrine infertility (Ehrmann, 2005). Weight reduction can reverse this mechanism of infertility. While most studies report a reduced incidence of gestational diabetes mellitus (GDM), PIH and pre-eclampsia (PET) after bariatric surgery (Richards *et al*., 1987; Deitel *et al*., 1988; Wittgrove *et al*., 1998; Dixon *et al*., 2001; Skull *et al*., 2004; Dixon *et al*., 2005; Dao *et al*., 2006; Ducarme *et al*., 2007), Patel *et al*. (2008) found no significant difference in GDM, PIH and PET

Table I Overview of case–control studies

Reference	Type of surgery	Study population, prepregnancy age and BMI	Controls	Significant positive changes compared with control group	Significant negative changes compared with control group	No change compared with control group	Authors' conclusion
Sheiner *et al.* (2006)	Mixture	28 ♀ with GDM age 28.6 y, 3.6% obese	7986 ♀ with GDM age 30.8 y, 1.5% obese	Low complication rate of surgery itself	↑ fertility treatments	Pregnancy, perinatal or labour characteristics	No worsening nor improvement of pregnancy outcome after bariatric surgery
Sheiner *et al.* (2004)	Mixture	298 ♀ age 29.1 ± 5.7 y, 10.4% obese	158 912 ♀ age 28.3 ± 5.9 y, 1.2% obese		↑ fertility treatment ↑ PROM ↑ labour induction ↑ failed induction ↑CS ↑ macrosomia ↑ IUGR	Other pregnancy or perinatal complications, gestational age	Pregnancy after bariatric surgery is not associated with adverse perinatal outcome, but there is a higher risk for CS, fertility treatment, PROM, macrosomia and labour induction
Deitel *et al.* (1988)	Mixture	7 ♀ with 9 pregnancies no age/BMI available	86 ♀ with 274 pregnancies	↑ fertility ↓ GDM ↓ PIH ↓ PET ↓ venous thrombosis ↓ CS		Birthweight	Incidence of obstetric complications returns towards normal after weight loss surgery in obese women
Ducarme *et al.* (2007)	LAGB	13 ♀ age 31.5 ± 5.7 y, BMI 34.8 ± 3.2 kg/m^2	414 ♀ age 31.0 ± 6.0 y, BMI 35.8 ± 4.0 kg/m^2	↓ GDM ↓ PET ↑ spontaneous vaginal delivery ↑ VBAC ↓ CS ↓ GWG ↓ macrosomia ↓ low birthweight ↓ PET ↑ spontaneous vaginal delivery ↑ VBAC ↓ CS ↓ GWG ↓ macrosomia ↓ low birthweight		Labour induction, PIH, pregnancy duration, post-partum haemorrhage	Risk for obstetric complications is reduced in women after LAGB compared with women without LAGB
Dixon *et al.* (2005)	LAGB	79 pregnancies, age 29.9 ± 4.7 y, no BMI available	1) Pre-LAGB pregnancies 2) Obese matched controls	↓ GDM ↓ PIH ↓ PET ↓ GWG		Birthweight	Pregnancy risk after LAGB is comparable to risk of general public
Skull *et al.* (2004)	LAGB	49 pregnancies, age 31 y, BMI 32.8 kg/m^2	Same ♀ with 31 preoperative pregnancies, age 27 y, BMI 34.1 kg/m^2	↓ GDM ↓ PIH ↓ PET ↓ GWG		Obstetric complications, CS Neonatal complications	Pregnancy after LAGB is safe

Continued

Table I *Continued*

Reference	Type of surgery	Study population, prepregnancy age and BMI	Controls	Significant positive changes compared with control group	Significant negative changes compared with control group	No change compared with control group	Authors' conclusion
Bilenka *et al.* (1995)	VBG	9 ♀ with 14 pregnancies, age 32 ± 5 y, weight loss 35 ± 11 kg, no BMI available	Same 9 ♀ with 18 pregnancies, 1 terminated mean BMI 42.2 ± 4.6 kg/m^2	↑ fertility ↓ spontaneous miscarriage ↓ complicated pregnancies Normal birthweights			VBG is procedure of choice for obese women with pregnancy wish
Patel *et al.* (2008)	RYGB	26 ♀, age 34.1 ± 4.5 y, BMI 32.5 ± 7.2 kg/m^2	188 non-obese, 39 obese and 27 severely obese controls	Comparable to non-obese and obese control: GWG, fetal birthweight, macrosomia and CS	Comparable to severely obese: SGA and anaemia 2 cases with small bowel obstruction	GDM PIH PET Premature delivery	Pregnancy after RYGB is safe: perinatal complications are similar to non-obese patients and lower than obese and severely obese patients
Wittgrove *et al.* (1998)	RYGB	40 ♀ with 49 pregnancies, no age/BMI available	17 preoperative pregnancies	↓ GDM ↓ CS ↓ GWG ↓ macrosomia No anaemia		Preterm delivery	Post-operative group had fewer complications than preoperative group
Marceau *et al.* (2004)	BPD	132 ♀ with 251 pregnancies no age/BMI available	594 ♀ with 1577 pregnancies	↑ fertility Normal GWG ↓ macrosomia	↑ SGA 2.5% albumin deficient, requiring PN	High miscarriage rate, premature delivery, stillbirths, malformation	Weight loss after BPD improves reproductive function. Delaying pregnancy after surgical weight loss and prenatal supplementation is recommended
Richards *et al.* (1987)	RYGB	57 pregnancies, age 32 ± 5 y, no BMI available	57 controls matched to preoperative weight age 29 ± 4y	↓ PIH ↓ GWG ↓ average birthweight ↓ LGA		CS, premature delivery, blood transfusion, SGA, perinatal death	Pregnancy after RYGB is safe

BMI, body mass index; BPD, biliopancreatic diversion; CS, Caesarean section; GDM, gestational diabetes mellitus; GWG, gestational weight gain; IUGR, intrauterine growth restriction; LAGB, laparoscopic adjustable gastric banding; LGA, large for gestational age; PET, pre-eclampsia; PIH, pregnancy-induced hypertension; PN, parenterale nutrition; PROM, preterm rupture of membranes; RYGB, Roux-en-Y gastric bypass; SGA, small for gestational age; VBAC, vaginal birth after Caesarean section; VBG, vertical banding gastroplasty.

Table II **Overview of cohort studies**

Reference	Surgery	Study population, age (y), BMI (kg/m^2)	sAB (%)	GDM (%)	PIH (%)	PET (%)	PTD (%)	CS (%)	Macrosomia (%)	SGA (%)	Others
Bar-Zohar *et al.* (2006)	LAGB	81 pregnancies, age NA, BMI 30.3 ± 3	NA	16	7.4	NA	NA	20.0	NA	NA	2.4% band slippage resulting vomiting, dehydration, electrolyte disturbances
Dixon *et al.* (2001)	LAGB	22 pregnancies, age 28.8 ± 4.4, BMI 35 ± 7	4.3	4.5	4.5	NA	0	13.6	4.5	0	1 patient with hyperemesis, requiring post-natal removal of all fluid in LAGB 1 patient with symptomatic gallstones
Weiss *et al.* (2001)	LAGB	7 pregnancies, age 33 ± 4.1, BMI 34.8 ± 5.8	28.6	0	0	0	0	28.6	0	14.3	1 intragastric band migration, 1 balloon defect, required re-operation
Martin *et al.* (2000)	LAGB	23 pregnancies, age 29, BMI NA	8.7	0	0	0	0	22.2	0	0	
Dao *et al.* (2006)	RYGB	Early group†	23.8	0	4.8	0	4.8	40.0	0	NA	4.8% anaemia, 4.8% cholelithiasis requiring hospitalization
		Late group‡	0	0	0	7.7	15.4	58.8	0	NA	0% nutritional deficiencies, 7.7% placental abruption
Friedman *et al.* (1995)	BPD	152 pregnancies, age 31.4, BMI NA	11.4	0	0.7	9.0	15.3	44	NA	27.8	1.3% Perinatal deaths, 21% required TPN
Printen and Scott (1982)	BPD	54 pregnancies, age NA, BMI NA	4.0	NA	NA	NA	15.2	10.5	NA	18.4	2.6% microcephalic child, 5.3% required parenterale iron, 2.6% perinatal death

BMI, body mass index, BPD, biliopancreatic diversion; CS, Caesarean section; GDM, gestational diabetes mellitus; LAGB, laparoscopic adjustable gastric banding; NA, not available; PET, pre-eclampsia; PIH, pregnancy-induced hypertension; PTD, preterm delivery; RYGB, Roux-en-Y gastric bypass; sAB, spontaneous miscarriage; SGA, small for gestational age; TPN, total parenteral nutrition.

†21 pregnancies, age 32 y, BMI 35 kg/m^2.

‡13 pregnancies, age 34 y, BMI 28 kg/m^2.

between the RYGB treated, non-obese, obese and severely obese groups (Patel et al., 2008). Sheiner et al. (2004) even reported higher rates of chronic hypertension (5.4% versus 1.7%, $P < 0.001$) and GDM (9.4% versus 5.0%, $P = 0.001$) after bariatric surgery, but this association was no longer significant after multiple logistic regression analysis (Sheiner et al., 2004).

The incidence of CS is increased both in obese and morbidly obese patients. Overall, bariatric surgery does not appear to reduce the risk for CS. The CS incidence in a recent cohort was even significantly higher in the bariatric surgery group after controlling for confounders (25.2% versus 12.2%; OR 2.4, $P < 0.001$) (Sheiner et al., 2004). However, there are as many case–control studies reporting a decreased incidence (Deitel et al., 1988; Wittgrove et al., 1998; Ducarme et al., 2007) as there are case–control studies not showing a significant difference between the groups (Richards et al., 1987; Skull et al., 2004; Patel et al., 2008).

Very few studies report on neonatal deaths and congenital malformations. The largest report is from a retrospective study by Sheiner et al. (2004). They described 298 deliveries after bariatric operations, including restrictive and malabsorptive procedures, and compared outcomes to 159 210 deliveries in the period between 1988 and 2002. The perinatal mortality rate and the incidence of congenital malformations were not significantly different between the groups: 0.3% versus 1.5% ($P = 0.102$) and 5.0% versus 4.0% ($P = 0.355$) (Sheiner et al., 2004). This was also the case in the study by Richards et al. (1987). They reported an important observation: seven infants from the post-operative group and three infants from the control group required hospitalization of more than 7 days (Richards et al., 1987). The second largest study, a prospectively collected cohort of 239 pregnancies after BPD, reported a higher incidence of perinatal death and congenital malformations in pregnancies after bariatric surgery: four deaths and three malformations. Two newborns died at delivery, for unknown causes and with unknown birthweight. One died after a surgical attempt to correct a diaphragmatic eventration and another one died after surgery for gastro-intestinal obstruction. Other congenital malformations included neural tube defects (0.8%) and rectal atresia (0.4%) that was successfully corrected surgically (Friedman et al., 1995). Dixon et al. (2005) reported one case of duodenal atresia and one stillbirth of a 3 200 g infant at 41 weeks in 79 pregnancies after bariatric surgery (Dixon et al., 2005). In another study population of 38 newborns, 1 child died of an unknown cause and another child was born with microcephaly, who subsequently demonstrated severe growth and developmental retardation (Printen and Scott, 1982). No neonatal deaths nor congenital anomalies were reported in two smaller studies (Dixon et al., 2001; Bar-Zohar et al., 2006).

Miscarriage

An impressive decline in the rate of miscarriage (from 33.3% to 7.8%) has been observed following the Mason type of bariatric procedure (Bilenka et al., 1995). However, this reported decrease came from a small case series of nine patients and the pregnancies prior to the surgery served as the controls. Further evidence supporting this decline in miscarriage rates after bariatric surgery is lacking. The high preoperative miscarriage rate (21.6%) compared with the general population in one study persisted after BPD (26.0%) (Marceau et al., 2004). The cohort study of Friedman reported on 239 pregnancies after BPD of which 28 (11.7%) ended in spontaneous miscarriage. This rate was not different to that prior to BPD (16.9%). Two medical abortions were performed for unclear nutritional causes and two for neural tube defects (0.8%). The mean time interval between pregnancy and operation was 42.7 months (range 2–173 months) (Friedman et al., 1995). Miscarriage rates remain high and range from 4.3% up to 29% after restrictive procedures (Deitel et al., 1988; Martin et al., 2000; Dixon et al., 2001; Weiss et al., 2001). The incidence of spontaneous miscarriage reported after RYGB and BPD was 34.7% (Wittgrove et al., 1998) and 4% (Printen and Scott, 1982), respectively. No miscarriages were reported by Patel et al. (2008) or by Richards et al. (1987). However, in the latter study, obstetrical information was collected though mailed questionnaires and the miscarriage rate could be underestimated as a result of the low response rate (42%). Skull et al. (2004) did not even report on early miscarriage because patients usually had not reported this. Ducarme et al. (2007) excluded intrauterine death and fetal loss before 22 weeks for unknown reasons.

Prematurity

The prematurity rate does not appear to significantly change in pregnancies after bariatric surgery compared with pregnancies prior to surgery (Wittgrove et al., 1998; Marceau et al., 2004; Dixon et al., 2005) or compared with a BMI-matched control group (Richards et al., 1987; Dixon et al., 2005; Patel et al., 2008). Patel et al. (2007) did not find a significant difference in the prematurity rate between the post-RYGB, non-obese, obese and severely obese groups. Worryingly, in a large study, a positive association between premature rupture of the membranes and bariatric surgery (OR 1.9, $P = 0.001$) was observed (Sheiner et al., 2004).

Birthweight

There is a linear association between maternal prepregnancy BMI and mean birthweight (Getahun et al., 2007). The risk of macrosomia is increased with maternal obesity (Ehrenberg et al., 2004). As expected, a significant decrease in mean birthweight was observed after the surgery-induced weight loss compared with pre-operative pregnancies (Richards et al., 1987; Marceau et al., 2004). This decrease was also confirmed in a recent study by Patel et al. After RYGB, mean birthweight and the incidence of macrosomia were significantly lower compared with severely obese patients, and similar to those of non-obese and obese patients (Patel et al., 2008). Compared with a matched obese group, mean birthweight was also significantly lower in an LAGB group. However this was not different from the birthweight of pre-LAGB pregnancies (Dixon et al., 2005). On the other hand, three studies found no significant difference in mean birthweight between operative and control groups (Deitel et al., 1988; Skull et al., 2004; Ducarme et al., 2007). One study even reported an increase mean birthweight in the post-operative group compared with the control group (Sheiner et al., 2004). The multiple logistic regression revealed a significant association between fetal macrosomia (birthweight >4000 g) (OR 2.1, $P < 0.001$) and previous bariatric surgery. No other studies confirmed this association. In contrast, a decreased incidence of macrosomia (birthweight >4000 g or >90th percentile) was observed after bariatric surgery. The range of the reported incidences of macrosomia in the case–control studies was 5.5–11.6% compared with the range of 14.6–34.8% in the control groups (Richards *et al*., 1987; Wittgrove *et al*., 1998; Marceau *et al*., 2004; Dixon *et al*., 2005; Ducarme *et al*., 2007). The cohort of Dixon *et al*. (2001) included four macrosomic newborns, of which one was born from a mother with GDM. No macrosomic infants were born in some other study populations (Friedman *et al*., 1995; Martin *et al*., 2000; Weiss *et al*., 2001; Dao *et al*., 2006).

Unfortunately, bariatric surgery is not only associated with decreased birthweight and reduced incidence of macrosomia. The incidence of intrauterine growth restriction (IUGR) and small for gestational age (SGA) appears to be increased. Comparing 162 post-operative pregnancies to pregnancies prior to BPD, more SGA infants were reported (9.6% versus 3.1%) (Marceau *et al*., 2004). According to the author, this remained within normal region limits. Sheiner *et al*. (2004) also observed a higher incidence of IUGR (5% versus 2% $P < 0.001$), but this significant association with bariatric surgery did not remain after multivariable analysis (OR 1.4, $P = 0.063$). The incidence of SGA after RYGB was higher (11.5%) compared with non-obese patients (0.5%, $P < 0.001$), but not significantly different from obese (2.6%) and severely obese patients (3.7%) (Patel *et al*., 2008). In Friedman's study, 27.8% of the infants born to a mother with a BPD were SGA, although 17 of the 40 had a weight >2500 g (Friedman *et al*., 1995). Seven of 38 deliveries (18.4%) in the cohort of Printen and Scott (1982) were premature, either by gestational age or low birthweight. No statistically significant difference in the incidence of SGA infants (7.0% versus 3.5%, NS) was shown by Richards *et al*. (1987) and Dixon *et al*. (2005). In the study of Rand and Macgregor, five infants (24%) had a birthweight less than 2 500 g. However, this could likely be attributed to maternal smoking and not necessarily to the surgery since four of the five mothers smoked (Rand and Macgregor, 1989). Counterbalancing these results, the rates for low birthweight (birthweight <10th percentile) (7.7% versus 10.6%) were significantly lower among the operative cases compared with the controls in study by Ducarme *et al*. (2007).

Gestational weight gain

The Institute of Medicine recommends a minimum GWG of 6 kg for obese pregnant women without defining the upper limit due to lack of clinical data (National Research Council and Institute of Medicine, 2007). As GWG is an important predictor for birthweight and postpartum weight retention, limiting GWG should be recommended in these pregnancies (Gore *et al*., 2003; Ehrenberg *et al*., 2004). Most obese pregnant women, however, have an excessive GWG (Olafsdottir *et al*., 2006). After bariatric surgery, a significantly lower GWG compared with a BMI-matched control group or to pregnancies prior to surgery has been observed in several case–control studies (Richards *et al*., 1987; Wittgrove *et al*., 1998; Dixon *et al*., 2001; Skull *et al*., 2004; Dixon *et al*., 2005; Ducarme *et al*., 2007). In two studies focusing on pregnancies after LAGB, active management was used (Dixon *et al*., 2001; Dixon *et al*., 2005). This included removal of all band fluid as early as possible in the pregnancy to minimize the effect on emesis, the addition of fluid after 14 weeks gestation or later if GWG was excessive and third again a removal of all fluid at 36 weeks gestation to minimize its impact on delivery and the establishment of lactation. Dixon *et al*. (2005) strongly advise band adjustments be made during pregnancy in view of the favourable maternal weight outcomes in their study ($P = 0.027$). In one study, mean GWG of women after RYGB (14.6 ± 11.2 kg) was higher than in the severely obese (6.3 ± 6.7 kg, $P = 0.031$) and comparable to the GWG of non-obese (13.5 ± 9.4 kg, $P = 0.425$) and obese (11.8 ± 8.9 kg, $P = 0.247$) patients (Patel *et al*., 2008). Just like the GWG of obese women without a history of weight loss surgery, GWG in post-operative pregnancies can vary widely (Printen and Scott, 1982; Martin *et al*., 2000; Weiss *et al*., 2001). A weight loss of −21 kg to a weight gain of 25 kg have been reported in the same study population (Friedman *et al*., 1995). One might believe that enlarging the diameter of the banding to relieve the nausea and vomiting automatically results in excessive weight gain. This is not necessarily the case in pregnant women (Martin *et al*., 2000; Weiss *et al*., 2001). In all five pregnant women studied by Weiss *et al*. (2001), the LAGB was deflated. This resulted in a weight gain of 2.0, 20.3, 25.0 and 38.5 kg and one weight loss of 7.7 kg, respectively. Martin *et al*. also removed all band fluid in four patients, of which two gained weight (31.0 and 39.0 kg) and one lost 17.6 kg during pregnancy. Even if the band diameter is kept constant, GWG can vary largely (−7.6 to 25.0 kg) (Martin *et al*., 2000).

The time between the surgery and the time of conception probably influences GWG. Dao *et al*. (2006) found a statistically significant difference in GWG between a group pregnant early after surgery compared with a late group: 1.81 kg (range: −31.75 to 20.41 kg) versus 15.42 kg (range: 5.90–34.02 kg) ($P = 0.002$).

Interestingly, in some study populations, the prepregnancy BMI after bariatric surgery is still comparable to the prepregnancy BMI of preoperative pregnancies. Mean prepregnancy BMI in the post-operative group of Skull *et al*. (2004) was 32.8 versus 34.1 kg/m^2 in preoperative pregnancies. Mean time from operation to conception was 22 months. Despite the bariatric operation, obesity was still present in 10.7% of the 298 women (Sheiner *et al*., 2004). On the other hand, significant decreases in BMI after surgery compared with prepregnancy BMI have also been reported (Dixon *et al*., 2001; Weiss *et al*., 2001; Bar-Zohar *et al*., 2006).

Mechanical complications after restrictive procedures

The increased abdominal pressure, the anatomical repositioning of the intra-abdominal organs during pregnancy and the frequent occurrence of emesis during pregnancy predispose to technical problems with the gastric band. Band migration resulting in vomiting, severe dehydration, electrolyte disturbances and band leakage is reported in up to 29% of cases (Weiss *et al*., 2001; Bar-Zohar *et al*., 2006). Removal of the LAGB at laparotomy after gastric prolapse was required in 4% of the patients (Skull *et al*., 2004). One pouch dilation was reported in a study population of 28 women (Sheiner *et al*., 2006). No mechanical complications were reported in four other studies (Deitel *et al*., 1988; Martin *et al*., 2000; Dixon *et al*., 2001; Dixon *et al*., 2005; Ducarme *et al*., 2007).

Timing of pregnancy after bariatric surgery

Pregnancies conceived early after surgery raise an additional concern, especially with respect to the rate of miscarriage and fetal growth, since conception falls within a period of rapid weight loss. Dao *et al*.

reported a remarkable trend towards more miscarriages in the early group (24%) compared with the late group (0%). Although this decrease was not statistically significant because of the small number of subjects, the authors suggest caution about the potential for miscarriage during the first post-operative year (Dao *et al*., 2006). In contrast, the miscarriage rate in the population of Marceau *et al*. (2004) was unaffected by the interval between pregnancy and operation. In the study of Patel *et al*., no spontaneous miscarriages or stillbirths occurred within the early or late group. However, more preterm deliveries appeared to occur in pregnancies conceived within the first year after surgery (Patel *et al*., 2008). This is not confirmed by the results of Dixon *et al*. (2005) and Dao *et al*. (2006) who found no statistical difference in preterm delivery rates. The early group of Patel *et al*. (2008) also required oral protein supplementation more frequently than the group with pregnancies occurring >18 months after RYGB (66.7% versus 7.1%). A significantly lower GWG has been observed between early and late groups (Dixon *et al*., 2005; Dao *et al*., 2006). All studies consistently report no difference in birthweight, IUGR or SGA, the incidence of GDM, PIH and CS, between pregnancies conceived within the first post-operative year and those conceived thereafter (Rand and Macgregor, 1989; Dixon *et al*., 2005; Dao *et al*., 2006). Marceau *et al*. (2004) compared birthweights of infants born within 2 years of surgery with those born thereafter and reported no difference. In a Letter to the Editor, Rand and Macgregor (1989) reported on 21 babies to 18 women with a history of gastric bypass surgery. Ten conceptions were during the first post-operative year. The letter confirms that the results of the studies mentioned above, birthweight and the rate of CS, other delivery complications, neonatal jaundice and birthweight of less than 2 500 g, were statistically comparable in the early and later conceptions.

Besides the case–control and cohort studies summarized previously in this review, the literature of pregnancy after bariatric surgery consists of a rapidly growing number of case reports and small case series. Two main categories can be distinguished: surgical complications and the complications related to severe nutritional deficiencies (Table III).

Intestinal obstructions

The available literature contains 11 case reports of intestinal herniation, volvulus or obstruction in pregnant women with a prepregnancy history of RYGB. Additionally, three intestinal obstructions have been reported in case–control studies (Marceau *et al*., 2004; Patel *et al*., 2008). The general incidence of intestinal obstruction after RYGB is up to 5% (Wax *et al*., 2007b). There are three specific locations for internal hernia formation: transverse mesocolon defect; Petersen's space (the area between the posterior aspect of the mesentery of the Roux limb and the transverse mesocolon); and jejunojejunostomy mesenteric defect. It is believed that intestinal hernias in pregnancy are created by the increased intra-abdominal pressure. Most cases of intestinal obstruction in pregnancy are due to adhesions from previous surgery. An obstruction is more likely to develop at three time-point periods during a gestation: at mid pregnancy when the uterus becomes an abdominal organ and puts pressure on the intestine; at term when the fetal head descends; and in the post-partum period with rapid involution of the uterus (Kakarla *et al*., 2005).

If untreated, complications of internal hernia could lead to bowel strangulation and/or anastomotic disruption, as well as dilation of the bypassed stomach. Perforation (9.1%) and death (1.6%) are potential consequences (Higa *et al*., 2003). In cases of an intestinal hernia or obstruction, prompt recognition and intervention is required for survival of both mother and child. Correct diagnosis can be a problem, since the symptoms of epigastric pain or discomfort, nausea and postprandial vomiting seen in all 11 cases are non-specific and common among pregnant women. If confirmatory imaging is required, a computed tomography scan with contrast is suggested to be reliable. An exploratory laparotomy might be necessary. Both imaging studies and surgical explorations are often delayed in pregnant patients. Maternal mortality was reported in three cases (Graubard *et al*., 1988; Moore *et al*., 2004; Loar *et al*., 2005). In only one of these the baby was not lost (Loar *et al*., 2005). The course after laparoscopic intervention was uncomplicated for the other eight patients and their baby (Baker and Kothari, 2005; Charles *et al*., 2005; Kakarla *et al*., 2005; Ahmed and O'Malley, 2006; Bellanger *et al*., 2006; Wang *et al*., 2007; Wax *et al*., 2007b).

Nutritional deficiencies

Mild nutritional deficiencies are frequent after bariatric surgery. More serious deficiencies appear more often after malabsorption-inducing surgery compared with the pure restrictive procedures. Since nutritional requirements for most nutrients are increased during pregnancy, the risk for clinically relevant deficiencies increases. This is especially important as the poor nutritional status of the mother can be exacerbated by serious vomiting or nausea during the pregnancy. Unfortunately, very few prospective studies have addressed this issue, and most severe complications are only reported as case reports. In pregnant women, deficiencies for protein, electrolytes, calcium and specific vitamins like vitamin A, D, K and B_{12} have been described (Granstrom *et al*., 1990; Martens *et al*., 1990; Adami *et al*., 1992; Grange and Finlay, 1994; Wardinsky *et al*., 1995; Weissman *et al*., 1995; Gurewitsch *et al*., 1996; Huerta *et al*., 2002; Campbell *et al*., 2005; Cools *et al*., 2006; Smets *et al*., 2006; Van Mieghem *et al*., 2008). When inadequately supplemented during pregnancy, serious health problems may occur in the babies such as fetal growth retardation, oligohydramnios, electrolyte imbalances, cerebral haemorrhages due to vitamin K deficiency, bilateral micropthalmia and permanent retinal damage due to vitamin A deficiency, anaemia due to vitamin B_{12} deficiency and even fetal deaths (Granstrom *et al*., 1990; Martens *et al*., 1990; Adami *et al*., 1992; Grange and Finlay, 1994; Wardinsky *et al*., 1995; Weissman *et al*., 1995; Gurewitsch *et al*., 1996; Cools *et al*., 2006). Vitamin B_{12} deficiency can be expected after all surgical procedures since the production of the intrinsic factors required for uptake through specific receptors is reduced. Vitamin B_{12} deficiency in the mother is reflected in the concentration in the breast milk and therefore results in low concentrations in the baby (Grange and Finlay, 1994; Wardinsky *et al*., 1995; Campbell *et al*., 2005). A significant fat malabsorption in the mother also influences the energy content of breast milk and may affect the post-natal growth of the baby (Martens *et al*., 1990). To overcome these specific problems, both enteral and/or parenteral nutrition, in combination with specific supplementation of micronutrients, may be indicated during pregnancy in this group of women (Adami *et al*., 1992; Gurewitsch *et al*., 1996). Some cohort

Table III Overview of case reports or case series

Reference	Type of surgery	Interval operation and pregnancy	Maternal complication	Fetal complication	Long-term outcome
Wang *et al.* (2007)	RYGB	2 months	Internal hernia		Uncomplicated
Wax *et al.* (2007a, b)	RYGB	12 months	Intussusception		Uncomplicated
Bellanger *et al.* (2006)	RYGB	24 months	Small bowel obstruction		Uncomplicated
Ahmed and O'Malley (2006)	RYGB	8 months	Internal hernia		Uncomplicated
Baker and Kothari (2005)	RYGB	4 months	Internal hernia		Uncomplicated
Loar *et al.* (2005)	RYGB	NA	Small bowel volvulus	Preterm delivery	Maternal death
Kakarla *et al.* (2005)	RYGB	9 months	Internal herniation	Preterm delivery	Uncomplicated
Kakarla *et al.* (2005)	RYGB	30 months	Small bowel herniation		Uncomplicated
Charles *et al.* (2005)	RYGB	6 months	Small bowel herniation		Uncomplicated
Moore *et al.* (2004)	RYGB	18 months	Small bowel herniation		Maternal + fetal deaths
Graubard *et al.* (1988)	BPD	3 years	Small bowel obstruction leading to maternal death	Fetal death	Maternal + fetal deaths
Smets *et al.* (2006)	BPD	8 years	Vit A deficiency	Bilateral microphthalmia	—
Huerta *et al.* (2002)	BPD	13 years	Vit A deficiency	Vit A deficiency	Unknown
Grange and Finlay (1994)	BPD	24 months	Subclinical Vit B_{12} deficiency	Failure to thrive, anaemia and neutropenia	Uncomplicated
Wardinsky *et al.* (1995)	RYGB	6 years	Vit B_{12} deficient breast milk	macrocytic anaemia, Vit B_{12} and folate deficient	Uncomplicated
Campbell *et al.* (2005)	GB	32 months	Asymptomatic Vit B_{12} deficiency	Asymptomatic Vit B_{12} deficiency	Uncomplicated
Gurewitsch *et al.* (1996)	GB	4 years	Iron deficiency anaemia		Uncomplicated
Martens *et al.* (1990)	GB	16 months	Anaemia during pregnancy, low fat content breast milk	Failure to thrive	Uncomplicated
Adami *et al.* (1992)	BPD	2 months	Severe protein malnutrition requiring PN via central vein	Reduced fetal growth	Uncomplicated with normal weight baby
Adami *et al.* (1992)	BPD	3 years	Severe protein malnutrition requiring PN via central vein	Reduced fetal growth	Uncomplicated with normal weight baby
Adami *et al.* (1992)	BPD		11 cases with moderate malnutrition requiring PN via peripheral vein	5 SGA babies	Uncomplicated
Cools *et al.* (2006)	BPD	3 years	Abdominal pain at 33 weeks	Fetal hydrops, congenital abnormalities, anaemia, prolonged coagulation	Perinatal death
Cools *et al.* (2006)	BPD	2 months	Unknown	Unknown	Failure to thrive
Cools *et al.* (2006)	BPD	2 years	Nutritional deficiencies, hypoplastic anaemia,	Multiple congenital abnormalities, preterm delivery, severe anaemia,	Severe retardation, epilepsy, blind, deaf
Cools *et al.* (2006)	BPD	18 months	Nutritional deficiencies no gestational weight gain	Preterm delivery	Uncomplicated
Cools *et al.* (2006)	BPD	3 years	Preterm contractions 22 weeks		Perinatal death
Cools *et al.* (2006)	BPD	5 years	Preterm contractions 27 weeks	Hydrocephaly, atrophy, hypoplastic corpus callosum	Retarded, vision disturbances, VP shunt
Cools *et al.* (2006)	BPD	7 years	Nutritional deficiencies preterm contractions for which cerclage	Preterm delivery	Uncomplicated
Cools *et al.* (2006)	BPD	18 months	Nutritional deficiencies no gestational weight gain	Cystic and haemorrhagic zones bilateral frontparietal, anaemia, nutritional deficiencies, prolonged coagulation	Epilepsy, good development at age of 2 months

Continued

Table III *Continued*

Reference	Type of surgery	Interval operation and pregnancy	Maternal complication	Fetal complication	Long-term outcome
Granstrom *et al.* (1990)	Mason	15 months	Malnutrition due to recurrent vomiting	growth retardation and oligohydramnions	Uncomplicated
Weissman *et al.* (1995)	Mason	11 years	Pre- and post-natal electrolyte imbalances, due to recurrent vomiting	Electrolyte imbalances	Perinatal death, uncomplicated for mother
Ramirez (1995)	Mason	4 years	GI haemorrhage after erosion of band	CS for abruptio placentae	Uncomplicated
Van Mieghem *et al.* (2008)	LAGB	2 years	Vitamin K deficiency	Cerebral haemorrhage	Perinatal death
Erez (2004)	LAGB	24 months	Perforated gastric ulcer	Preterm CS	Uncomplicated

BPD, biliopancreatic diversion; CS, Caesarean section; GB, gastric banding; GI, gastro-intestinal; LAGB, laparoscopic adjustable gastric banding; NA, not available; PN, parenteral nutrition; RYGB, Roux-en-Y gastric bypass.

studies already have reported an increased need for parenteral nutrition. In the cohort of Friedman *et al.* (1995), 21% of the women with a history of RYGB required parenteral nutrition, while all other patients received usual supplementations. Four patients required parenteral nutrition for severe hypoalbuminaemia (Marceau *et al.*, 2004).

Summary according to procedure type

The risk for a pregnancy complication is expected to be influenced by the procedure of bariatric surgery (Table IV). The incidence of GDM, PIH, PET and the birthweight seems unaffected by the procedure type. The results also indicate no difference in GWG after restrictive and malabsorptive procedures. Compared with pregnancies after LAGB, more preterm deliveries, CS and neonatal deaths have been reported after RYGB and BPD. The intestinal obstructions and nutritional deficiencies during pregnancies are primarily reported after RYGB and BPD (Graubard *et al.*, 1988; Martens *et al.*, 1990; Adami *et al.*, 1992; Grange and Finlay, 1994; Wardinsky *et al.*, 1995; Gurewitsch *et al.*, 1996; Huerta *et al.*, 2002; Marceau *et al.*, 2004; Moore *et al.*, 2004; Baker and Kothari 2005; Campbell *et al.*, 2005; Charles *et al.*, 2005; Kakarla *et al.*, 2005; Loar *et al.*, 2005; Ahmed and O'Malley 2006; Bellanger *et al.*, 2006; Cools *et al.*, 2006; Smets *et al.*, 2006; Wang *et al.*, 2007; Wax *et al.*, 2007a, b; Patel *et al.*, 2008), even though nutritional deficiencies can also occur after LAGB (Granstrom *et al.*, 1990; Weissman *et al.*, 1995; Van Mieghem *et al.*, 2008).

Discussion

The health and social burden of obesity drives more and more obese persons to seek for a long-term treatment for their problem. Thereby the number of bariatric surgical procedures is increasing, especially among young women of reproductive age. Both the restrictive procedures, including LAGB, and the RYGB procedure combining

Table IV **Summary of the incidence of study variables according to procedure type**

Outcome	Mixture of procedures[1]	Restrictive procedures[2]	RYGB[3]	Malabsorptive procedures[4]
Mean birthweight	3.275 (3.195–3.398)	3.276 (2.11–3.86)	2.938 (2.727–3.205)	2.926 (2.151–3.5)
GDM	4.3 (0–9.4)	4.3 (0–16)	2.4 (0–5.3)	0
PIH	7.7 (0–17.9)	5.2 (0–10)	3.5 (0–9.0)	0.7
PET	2.9 (0–5.7)	2.1 (0–7.7)	3.8 (0–7.7)	9.0
PTD	10.4	2.3 (0–7.7)	14.0 (4.8–26.9)	14.7 (13.6–15.3)
CS	20.3 (0–35.7)	18.3 (0–28.6)	44.3 (25.0–61.5)	24.9 (10.5–44.0)
GWG	NA	9.0 (3.7–15.6)	11.1 (1.8–15.4)	5.6 (1.5–9.1)
Neonatal deaths	0.1 (0–0.3)	1.3 (0–7.7)	0.7 (0–3.5)	2.0 (1.3–2.6)

Data are presented as mean (min–max). If only one study reported on the variable, no range is available.
CS, Caesarean section; GDM, gestational diabetes mellitus; GWG, gestational weight gain; NA, not available; PET, pre-eclampsia; PIH, pregnancy-induced hypertension; PTD, preterm delivery; RYGB, Roux-en-Y gastric bypass.
[1]Deitel *et al.*, 1988; Sheiner *et al.*, 2006; Sheiner *et al.*, 2004.
[2]Bab-Zohar *et al.*, 2006; Bilenka *et al.*, 1995; Dixon *et al.*, 2005; Dixon *et al.*, 2001; Ducarme *et al.*, 2007; Skull *et al.*, 2004; Weiss *et al.*, 2001.
[3]Dao *et al.*, 2006; Patel *et al.*, 2008; Richards *et al.*, 1987; Wittgrove *et al.*, 1998.
[4]Friedman *et al.*, 1995; Marceau *et al.*, 2004; Printen and Scott 1982.

restriction with malabsorption, are performed in this population. After the surgery-induced weight loss, fertility problems are largely reduced, and (unexpected) pregnancies are frequent (Weiss *et al*., 2001; Marceau *et al*., 2004; Dao *et al*., 2006; Roehrig *et al*., 2007). On one hand, the global results of most studies indicate a reduction in the risk of PET, GDM and macrosomia after surgically induced weight loss. However, benefits are counterbalanced by an increased risk for IUGR and SGA. The incidence of CS remains high and uncertainty remains regarding the risk for miscarriage and premature delivery. Strong evidence suggests that a pregnancy conceived within the first year after surgery would increase the risk for miscarriage and preterm delivery (Printen and Scott, 1982; Dao *et al*., 2006; Patel *et al*., 2007). Delaying the pregnancy appears beneficial, and it is therefore necessary to inform the patient adequately as oral contraception may be insufficient (Merhi, 2007).

It is important to note that the quality of the case–control and cohort studies was variable and that these studies exhibited considerable heterogeneity. Most studies are underpowered to detect possible significant differences in relevant outcomes, e.g. neonatal death or congenital malformations. Statements regarding safety have been made despite the presence of a small bowel obstruction, two birth malformations and some patients requiring parenteral nutrition in a small population of pregnant women (Friedman *et al*., 1995; Marceau *et al*., 2004; Patel *et al*., 2007). Second, no homogeneity exists in the control groups of the case–controls studies. In some studies, subjects' pregnancies before surgery serve as their own controls (Bilenka *et al*., 1995; Skull *et al*., 2004; Dixon *et al*., 2005). This has to be taken into account when incidences of obstetrical complications are compared, as some complications are related to parity (hypertensive disorders) rather than to bariatric surgery. Other studies select pregnancies in women without prior bariatric surgery as control group, requiring a proper matching of the groups for prepregnancy BMI, parity and age. Reporting bias and lack of specification of the bariatric procedure are other limitations. The expected complications after restrictive procedures and after combined procedures like RYGB are different, making specification important. Also, follow-up of the women needs to be long enough, as severe neonatal complications have been reported in pregnancies from 2 months up to 13 years after the bariatric procedure (Huerta *et al*., 2002; Cools *et al*., 2006). The danger of these methodological weaknesses is that they lead to an underreporting of maternal and fetal complications after bariatric surgery.

Both obstetricians and surgeons have therefore to consider these pregnant women as high-risk pregnancies. Even though the patient is now overweight or still obese instead of morbidly obese, it remains clear that for these patients intensive management during the preconceptional, prenatal and post-partum period is recommended (Table V). The preconceptional assessment first has to consist of a determination of the patient's nutritional status. Priority has to be given to folate, iron, vitamin B_{12}, calcium and fat-soluble vitamin deficiencies. If needed, supplementation has to be tailored to the individual needs of the patient and must be monitored monthly to adapt doses. A folic acid, vitamin B_{12} and iron supplementation is recommended preconceptionally. Next to the supplements, a dietician can detect significant deficiencies from their dietary history and give adequate advice for a healthy, varied diet. Delaying pregnancy until 12–18 months after surgery is still preferred, meaning that reliable contraception counselling is required.

Table V Management recommendations for pregnancy after bariatric surgery

Management recommendations
Preconception
Post-operative follow-up concerning nutritional status
Visits to a nutritionist to ensure a healthy and varied diet
Reliable contraception to delay pregnancy for approximately 1 year after surgery
Folic acid, vitamin B_{12} and iron supplementation
Prenatal care
Early prenatal consultation to determine baseline nutritional status, followed by regular check-ups
Nutritional supplementation tailored to the individual patient and the type of bariatric procedure performed.
Serial ultrasound examination focused on fetal growth restriction and malformations
Close monitoring of gestational weight gain
Awareness for possible intestinal obstruction during pregnancy
Fasting and 2 h postprandial glucose level monitoring to detect gestational diabetes mellitus
Post-partum care
Post-operative follow-up concerning nutritional status
Visits to a nutritionist to ensure a healthy and varied diet, and to guide further weight loss if required
Inform paediatrician of maternal bariatric surgery history and possible effects on the newborn
Recommend and support breastfeeding

During pregnancy, the monitoring of the nutritional status with targeted treatment of deficiencies remains a must. Detailed ultrasound examinations should focus on the detection of fetal growth restriction and malformations including neural tube defects. GWG also requires extra attention. In case of pregnancy after LAGB, active band management provides the best results concerning GWG. To detect gestational diabetes, alternative paths like fasting and 2 h postprandial glycaemia have to be used if the patient reports dumping complications. Even if there is a slight suspicion of intestinal obstruction during pregnancy, adequate clinical examination with imaging studies or surgical exploration is required.

In the post-partum period, the follow-up of the nutritional status cannot be discontinued. Breastfeeding should be encouraged in adequately substituted women, especially in obese women. The paediatrician should be informed of the maternal surgical history, as possible deficiencies still can affect the newborn through the breast milk.

Conclusion

The few case–control and cohort studies show an improvement in fertility rates and a reduction of obesity-related pregnancy complications after bariatric surgery. However, the incidence of IUGR and subsequent prematurity may be increased. Importantly, there are a growing number of case reports with life-threatening and even fatal complications for mother and child. Intensive follow-up with a multidisciplinary approach increases the chances for a successful pregnancy outcome. In the future, a prospective study with adequate statistical power is needed to provide scientifically sound recommendations for the management of pregnancy after bariatric surgery.

Author's role

I.G. performed the literature search, and R.D.V. and G.V. were involved in interpretation of data and revising the article critically for its content.

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References

Adami GF, Friedman D, Cuneo S, Cuneo G, Marinari G, Gandolfo P, Scopinaro N. Intravenous nutritional support in pregnancy. Experience following biliopancreatic diversion. *Clin Nutr* 1992;**11**:106–109.

Ahmed AR, O'Malley W. Internal hernia with Roux loop obstruction during pregnancy after gastric bypass surgery. *Obes Surg* 2006; **16**:1246–1248.

Baker MT, Kothari SN. Successful surgical treatment of a pregnancy-induced Petersen's hernia after laparoscopic gastric bypass. *Surg Obes Relat Dis* 2005;**1**:506–508.

Bar-Zohar D, Azem F, Klausner J, Abu-Abeid S. Pregnancy after laparoscopic adjustable gastric banding: perinatal outcome is favorable also for women with relatively high gestational weight gain. *Surg Endosc* 2006;**20**:1580–1583.

Bellanger DE, Ruiz JF, Solar K. Small bowel obstruction complicating pregnancy after laparoscopic gastric bypass. *Surg Obes Relat Dis* 2006; **2**:490–492.

Bilenka B, Ben-Shlomo I, Cozacov C, Gold CH, Zohar S. Fertility, miscarriage and pregnancy after vertical banded gastroplasty operation for morbid obesity. *Acta Obstet Gynecol Scand* 1995;**74**:42–44.

Buchwald H. Consensus conference statement bariatric surgery for morbid obesity: health implications for patients, health professionals, and third-party payers. *Surg Obes Relat Dis* 2005;**1**:371–381.

Bult MJ, van Dalen T, Muller AF. Surgical treatment of obesity. *Eur J Endocrinol* 2008;**158**:135–145.

Campbell CD, Ganesh J, Ficicioglu C. Two newborns with nutritional vitamin B12 deficiency: challenges in newborn screening for vitamin B12 deficiency. *Haematologica* 2005;**90**:45.

Charles A, Domingo S, Goldfadden A, Fader J, Lampmann R, Mazzeo R. Small bowel ischemia after Roux-en-Y gastric bypass complicated by pregnancy: a case report. *Am Surg* 2005;**71**:231–234.

Cools M, Duval EL, Jespers A. Adverse neonatal outcome after maternal biliopancreatic diversion operation: report of nine cases. *Eur J Pediatr* 2006;**165**:199–202.

Dao T, Kuhn J, Ehmer D, Fisher T, McCarty T. Pregnancy outcomes after gastric-bypass surgery. *Am J Surg* 2006;**192**:762–766.

Deitel M, Stone E, Kassam HA, Wilk EJ, Sutherland DJ. Gynecologic-obstetric changes after loss of massive excess weight following bariatric surgery. *J Am Coll Nutr* 1988;**7**:147–153.

Dixon JB, Dixon ME, O'Brien PE. Pregnancy after Lap-Band surgery: management of the band to achieve healthy weight outcomes. *Obes Surg* 2001;**11**:59–65.

Dixon JB, Dixon ME, O'Brien PE. Birth outcomes in obese women after laparoscopic adjustable gastric banding. *Obstet Gynecol* 2005; **106**:965–972.

Ducarme G, Revaux A, Rodrigues A, Aissaoui F, Pharisien I, Uzan M. Obstetric outcome following laparoscopic adjustable gastric banding. *Int J Gynaecol Obstet* 2007;**98**:244–247.

Ehrenberg HM, Mercer BM, Catalano PM. The influence of obesity and diabetes on the prevalence of macrosomia. *Am J Obstet Gynecol* 2004; **191**:964–968.

Ehrmann DA. Polycystic ovary syndrome. *N Engl J Med* 2005; **352**:1223–1236.

Erez O, Maymon E, Mazor M. Acute gastric ulcer perforation in a 35 weeks' nulliparous patient with gastric banding. *Am J Obstet Gynecol* 2004;**191**:1721–1722.

Friedman D, Cuneo S, Valenzano M, Marinari GM, Adami GF, Gianetta E, Traverso E, Scopinaro N. Pregnancies in an 18-year follow-up after biliopancreatic diversion. *Obes Surg* 1995;**5**:308–313.

Getahun D, Ananth CV, Peltier MR, Salihu HM, Scorza WE. Changes in prepregnancy body mass index between the first and second pregnancies and risk of large-for-gestational-age birth. *Am J Obstet Gynecol* 2007;**196**:530 e1–538.

Gore SA, Brown DM, West DS. The role of postpartum weight retention in obesity among women: a review of the evidence. *Ann Behav Med* 2003;**26**:149–159.

Grange DK, Finlay JL. Nutritional vitamin B12 deficiency in a breastfed infant following maternal gastric bypass. *Pediatr Hematol Oncol* 1994; **11**:311–318.

Granstrom L, Granstrom L, Backman L. Fetal growth retardation after gastric banding. *Acta Obstet Gynecol Scand* 1990;**69**:533–536.

Graubard Z, Graham KM, Schein M. Small-bowel obstruction in pregnancy after Scopinaro weight reduction operation. A case report. *S Afr Med J* 1988;**73**:127–128.

Guelinckx I, Devlieger R, Beckers K, Vansant G. Maternal obesity: pregnancy complications, gestational weight gain and nutrition. *Obes Rev* 2008;**9**:140–150.

Gurewitsch ED, Smith-Levitin M, Mack J. Pregnancy following gastric bypass surgery for morbid obesity. *Obstet Gynecol* 1996;**88**:658–661.

Higa KD, Ho T, Boone KB. Internal hernias after laparoscopic Roux-en-Y gastric bypass: incidence, treatment and prevention. *Obes Surg* 2003; **13**:350–354.

Huerta S, Rogers LM, Li Z, Heber D, Liu C, Livingston EH. Vitamin A deficiency in a newborn resulting from maternal hypovitaminosis A after biliopancreatic diversion for the treatment of morbid obesity. *Am J Clin Nutr* 2002;**76**:426–429.

Kakarla N, Dailey C, Marino T, Shikora SA, Chelmow D. Pregnancy after gastric bypass surgery and internal hernia formation. *Obstet Gynecol* 2005;**105**:1195–1198.

Karlsson J, Taft C, Ryden A, Sjostrom L, Sullivan M. Ten-year trends in health-related quality of life after surgical and conventional treatment for severe obesity: the SOS intervention study. *Int J Obes (Lond)* 2007; **31**:1248–1261.

Livingston EH. Obesity and its surgical management. *Am J Surg* 2002; **184**:103–113.

Loar PV 3rd, Sanchez-Ramos L, Kaunitz AM, Kerwin AJ, Diaz J. Maternal death caused by midgut volvulus after bariatric surgery. *Am J Obstet Gynecol* 2005;**193**:1748–1749.

Marceau P, Kaufman D, Biron S, Hould FS, Lebel S, Marceau S, Kral JG. Outcome of pregnancies after biliopancreatic diversion. *Obes Surg* 2004;**14**:318–324.

Martens WS 2nd, Martin LF, Berlin CM Jr. Failure of a nursing infant to thrive after the mother's gastric bypass for morbid obesity. *Pediatrics* 1990;**86**:777–778.

Martin LF, Finigan KM, Nolan TE. Pregnancy after adjustable gastric banding. *Obstet Gynecol* 2000;**95**:927–930.

Merhi ZO. Challenging oral contraception after weight loss by bariatric surgery. *Gynecol Obstet Invest* 2007;**64**:100–102.

Moore KA, Ouyang DW, Whang EE. Maternal and fetal deaths after gastric bypass surgery for morbid obesity. *N Engl J Med* 2004; **351**:721–722.

National Research Council and Institute of Medicine. Influence of pregnancy weight and child health. *Worshop Report. Committee on Children, Youth, and Families, Division of Behavioral and Social Sciences and Education and Food and Nutrition Board, Institute of Medicine*. Washington, DC: The National Academies Press, 2007.

Olafsdottir AS, Skuladottir GV, Thorsdottir I, Hauksson A, Steingrimsdottir L. Maternal diet in early and late pregnancy in relation to weight gain. *Int J Obes (Lond)* 2006;**30**:492–499.

Ono T, Guthold R, Strong K. WHO Global Comparable Estimates, 2005.

Patel JA, Colella JJ, Esaka E, Patel NA, Thomas RL. Improvement in infertility and pregnancy outcomes after weight loss surgery. *Med Clin North Am* 2007;**91**:515–528, xiii.

Patel JA, Patel NA, Thomas RL, Nelms JK, Colella JJ. Pregnancy outcomes after laparoscopic Roux-en-Y gastric bypass. *Surg Obes Relat Dis* 2008; **4**:39–45.

Poitou Bernet C, Ciangura C, Coupaye M, Czernichow S, Bouillot JL, Basdevant A. Nutritional deficiency after gastric bypass: diagnosis, prevention and treatment. *Diabetes Metab* 2007;**33**:13–24.

Printen KJ, Scott D. Pregnancy following gastric bypass for the treatment of morbid obesity. *Am Surg* 1982;**48**:363–365.

Ramirez MM, Turrentine MA. Gastrointestinal hemorrhage during pregnancy in a patient with a history of vertical-banded gastroplasty. *Am J Obstet Gynecol* 1995;**173**:1630–1631.

Rand CS, Macgregor AM. Medical care and pregnancy outcome after gastric bypass surgery for obesity. *South Med J* 1989;**82**: 1319–1320.

Richards DS, Miller DK, Goodman GN. Pregnancy after gastric bypass for morbid obesity. *J Reprod Med* 1987;**32**:172–176.

Roehrig HR, Xanthakos SA, Sweeney J, Zeller MH, Inge TH. Pregnancy after gastric bypass surgery in adolescents. *Obes Surg* 2007; **17**:873–877.

Santry HP, Gillen DL, Lauderdale DS. Trends in bariatric surgical procedures. *JAMA* 2005;**294**:1909–1917.

Schilling PL, Davis MM, Albanese CT, Dutta S, Morton J. National trends in adolescent bariatric surgical procedures and implications for surgical centers of excellence. *J Am Coll Surg* 2008;**206**:1–12.

Sheiner E, Levy A, Silverberg D, Menes TS, Levy I, Katz M, Mazor M. Pregnancy after bariatric surgery is not associated with adverse perinatal outcome. *Am J Obstet Gynecol* 2004;**190**:1335–1340.

Sheiner E, Menes TS, Silverberg D, Abramowicz JS, Levy I, Katz M, Mazor M, Levy A. Pregnancy outcome of patients with gestational diabetes mellitus following bariatric surgery. *Am J Obstet Gynecol* 2006; **194**:431–435.

Sjostrom L, Narbro K, Sjostrom CD, Karason K, Larsson B, Wedel H, Lystig T, Sullivan M, Bouchard C, Carlsson B *et al*. Effects of bariatric surgery on mortality in Swedish obese subjects. *N Engl J Med* 2007; **357**:741–752.

Skull AJ, Slater GH, Duncombe JE, Fielding GA. Laparoscopic adjustable banding in pregnancy: safety, patient tolerance and effect on obesity-related pregnancy outcomes. *Obes Surg* 2004;**14**:230–235.

Smets KJ, Barlow T, Vanhaesebrouck P. Maternal vitamin A deficiency and neonatal microphthalmia: complications of biliopancreatic diversion? *Eur J Pediatr* 2006;**165**:502–504.

Van Mieghem T, Van Schoubroeck D, Depiere M, Debeer A, Desmet K, Hanssens M. Fetal cerebral hemorrhage due to vitamin K deficiency after complicated bariatric surgery. *Obstet Gynecol* 2008;**112**:434–436.

Wang CB, Hsieh CC, Chen CH, Lin YH, Lee CY, Tseng CJ. Strangulation of upper jejunum in subsequent pregnancy following gastric bypass surgery. *Taiwan J Obstet Gynecol* 2007;**46**:267–271.

Wardinsky TD, Montes RG, Friederich RL, Broadhurst RB, Sinnhuber V, Bartholomew D. Vitamin B12 deficiency associated with low breast-milk vitamin B12 concentration in an infant following maternal gastric bypass surgery. *Arch Pediatr Adolesc Med* 1995;**149**:1281–1284.

Wax JR, Heersink D, Pinette MG, Cartin A, Blackstone J. Symptomatic hypoglycemia complicating pregnancy following Roux-en-Y gastric bypass surgery. *Obes Surg* 2007a;**17**:698–700.

Wax JR, Wolff R, Cobean R, Pinette MG, Blackstone J, Cartin A. Intussusception complicating pregnancy following laparoscopic Roux-en-Y gastric bypass. *Obes Surg* 2007b;**17**:977–979.

Weiss HG, Nehoda H, Labeck B, Hourmont K, Marth C, Aigner F. Pregnancies after adjustable gastric banding. *Obes Surg* 2001; **11**:303–306.

Weissman A, Hagay Z, Schachter M, Dreazen E. Severe maternal and fetal electrolyte imbalance in pregnancy after gastric surgery for morbid obesity. A case report. *J Reprod Med* 1995;**40**:813–816.

Wittgrove AC, Jester L, Wittgrove P, Clark GW. Pregnancy following gastric bypass for morbid obesity. *Obes Surg* 1998;**8**:461–464. discussion 465-6.

Woodard CB. Pregnancy following bariatric surgery. *J Perinat Neonatal Nurs* 2004;**18**:329–340.

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