Pregnancy and Fertility Following Bariatric Surgery

A Systematic Review

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Context Use of bariatric surgery has increased dramatically during the past 10 years, particularly among women of reproductive age.

Objectives To estimate bariatric surgery rates among women aged 18 to 45 years and to assess the published literature on pregnancy outcomes and fertility after surgery.

Evidence Acquisition Search of the Nationwide Inpatient Sample (1998-2005) and multiple electronic databases (Medline, EMBASE, Controlled Clinical Trials Register Database, and the Cochrane Database of Reviews of Effectiveness) to identify articles published between 1985 and February 2008 on bariatric surgery among women of reproductive age. Search terms included *bariatric procedures*, *fertility*, *contraception*, *pregnancy*, and *nutritional deficiencies*. Information was abstracted about study design, fertility, and nutritional, neonatal, and pregnancy outcomes after surgery.

Evidence Synthesis Of 260 screened articles, 75 were included. Women aged 18 to 45 years accounted for 49% of all patients undergoing bariatric surgery (>50 000 cases annually for the 3 most recent years). Three matched cohort studies showed lower maternal complication rates after bariatric surgery than in obese women without bariatric surgery, or rates approaching those of nonobese controls. In 1 matched cohort study that compared maternal complication rates in women after laparoscopic adjustable gastric band surgery with obese women without surgery, rates of gestational diabetes (0% vs 22.1%, $P<.05$) and preeclampsia (0% vs 3.1%, $P<.05$) were lower in the bariatric surgery group. Findings were supported by 13 other bariatric cohort studies. Neonatal outcomes were similar or better after surgery compared with obese women without laparoscopic adjustable gastric band surgery (7.7% vs 7.1% for premature delivery; 7.7% vs 10.6% for low birth weight, $P<.05$; 7.7% vs 14.6% for macrosomia, $P<.05$). No differences in neonatal outcomes were found after gastric bypass compared with nonobese controls (26.3%-26.9% vs 22.4%-20.2% for premature delivery, P=not reported [1 study] and $P=.43$ [1 study]; 7.7% vs 9.0% for low birth weight, P=not reported [1 study]; and 0% vs 2.6%-4.3% for macrosomia, P=not reported [1 study and $P=.28$ [1 study]). Findings were supported by 10 other studies. Studies regarding nutrition, fertility, cesarean delivery, and contraception were limited.

Conclusion Rates of many adverse maternal and neonatal outcomes may be lower in women who become pregnant after having had bariatric surgery compared with rates in pregnant women who are obese; however, further data are needed from rigorously designed studies.

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Obesity has reached epidemic levels in the United States and is a leading cause of health-related disorders.[1-14] Rates of surgical weight loss procedures have grown steeply and women account for many of these patients.[15] Large numbers of women in their childbearing years may undergo bariatric surgery, which may change fertility following weight loss, alter nutritional requirements during pregnancy, or impact contraception to prevent pregnancy. Our specific goals were to estimate the incidence of bariatric surgery in women aged 18 to 45 years and perform a systematic review to assess associations of bariatric surgery on pregnancy outcomes, including maternal and neonatal outcomes, nutritional adverse events, fertility, contraception, optimal time to delay pregnancy, and surgical complications during pregnancies.

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EVIDENCE ACQUISITION

Analysis of Trends in Surgery Utilization

The Nationwide Inpatient Sample,[16] a Healthcare Cost and Utilization Project data set, was used to produce national estimates of trends in bariatric surgical procedures between 1998 and 2005, the latest year for which data are available. The Nationwide Inpatient Sample is a 20% stratified sample of all inpatient stays nationally and includes data on 5 million to 8 million hospitalizations from roughly 1000 hospitals.

A comprehensive list of *International Classification of Diseases, Ninth Revision* procedure codes was used to identify patients who underwent bariatric surgery, accounting for changes in coding and types of procedures.[17] Rates of bariatric cases were calculated for each year. We determined the number of procedures among men and women aged 18 to 45 years. Percentage change from 1998 was calculated for each subsequent year.

Literature Search

Our literature search included Medline, EMBASE, Controlled Clinical Trials Register Database, and the Cochrane Database of Reviews of Effectiveness and captured articles published between 1985 and February 2008. Articles on bariatric surgery, including laparoscopic adjustable gastric banding (LAGB), vertical-banded gastroplasty (VBG), Roux-en-Y gastric bypass (gastric bypass), and biliopancreatic diversion/duodenal switch (BPD), were included. We used various search terms for each procedure (eg, Roux-en-Y gastric bypass: *gastric bypass*, *RYGB*, *laparoscopic gastric bypass*, and *open gastric bypass*). We also searched for fertility, contraception, pregnancy, weight management, neonatal outcomes, and nutritional deficiencies.

Study Inclusion

The literature search included review articles, randomized controlled trials, observational studies, and case reports. To be included, studies had to be an original research article and discuss 1 of the procedures and fertility or pregnancy outcomes. Two reviewers (M.A.M. and Z. L.) reviewed each study. Disagreements were resolved by consensus.

Data Abstraction and Synthesis of Results

Study results were abstracted into data tables. Because of heterogeneity in the patients, interventions, and outcomes, data pooling was not possible. Therefore, we summarized the data narratively. Outcomes included maternal pregnancy outcomes (gestational diabetes, hypertension, preeclampsia, cesarean delivery, nutritional deficiencies, surgical complications, and maternal weight gain), neonatal outcomes (premature delivery, birth weight, macrosomia, and perinatal mortality), fertility, the optimal time between surgery and pregnancy, and contraception efficacy.

Because we found no randomized trials, our evidence consisted of observational studies. We discriminated between studies based on how cases and comparison groups were identified. We considered a study less prone to bias, and consequently gave it more emphasis, if it enrolled a consecutive or random sample of surgery cases or pregnancies and used a concurrent comparison group that consisted of consecutive, random, or matched patients or pregnancies. Data presented herein included all cohort studies with a comparison group. Studies without a comparison group, case series, and case reports were used for descriptions of surgical complications or rare adverse events or to provide additional information about our study questions. Nutritional outcomes included both cohort and case series studies. A RAND biostatistician performed the statistical analyses (M.S.).

EVIDENCE SYNTHESIS

Incidence of Bariatric Surgery Among Women of Reproductive Age

The incidence of bariatric surgery in the United States increased by 800% between 1998 and 2005 (from 12 480 to 113 500 cases). Women accounted for 83% of procedures in the 18- to 45-year age group. Between 2003 and 2005, more than 50 000 women aged 18 to 45 years underwent inpatient bariatric surgery procedures annually (49% of all bariatric surgery cases). The number of inpatient bariatric procedures decreased in 2005. Reasons for the lower surgery rate in 2005 are unknown but could include a shift to bariatric surgery in the outpatient setting, which is not captured by the Nationwide Inpatient Sample.

Description of the Studies Identified by the Literature Search

Our search identified 1102 articles, of which 260 were screened and of which 75 were included in the review (FIGURE). One randomized controlled trial comparing surgical procedures was treated as a case series for pregnancy outcomes. Of the 185 excluded articles, 88 did not study bariatric surgery, 60 did not study a procedure of interest or did not include pregnant women, and 37 were review articles.

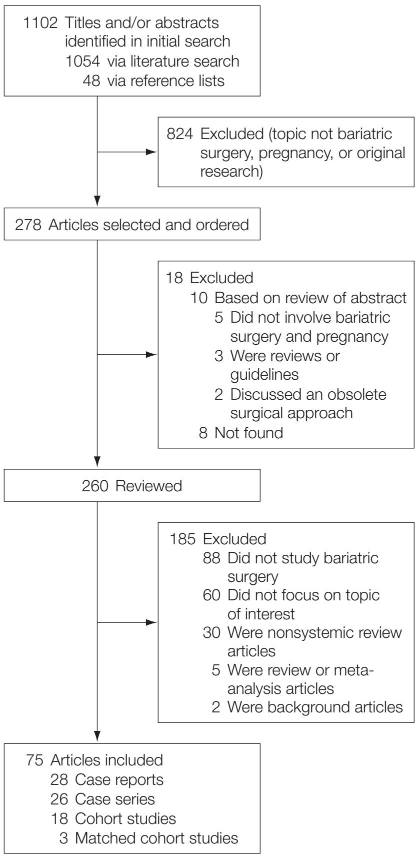
Three cohort studies by Ducarme et al,[18] Wax et al,[19] and Patel et al[20] compared outcomes for consecutive patients with postsurgery pregnancies (bariatric surgery group) with outcomes for consecutive nonsurgical patients (comparison group) who delivered in the same period and were matched to 1 or more characteristics (eg, body mass index [BMI, calculated as weight in kilograms divided by height in meters squared], age). Because these study designs are more rigorous, we present their results in detail.

The remaining cohort studies compared outcomes in selected pregnancies after bariatric surgery with outcomes in pregnancies before bariatric surgery (same women before surgery), selected nonobese patients, or population rates.

Risks for Pregnancies: Maternal Outcomes

Sixteen studies compared pregnancies following bariatric surgery with a comparison group.[18-33] The most com-

Figure. Flow of Eligible Studies of Bariatric Surgery Among Women of Reproductive Age



monly reported maternal outcomes were gestational diabetes, preeclampsia, pregnancy-induced hypertension, maternal weight gain, and cesarean delivery (TABLE 1).

Laparoscopic Adjustable Gastric Banding. Ducarme et al[18] compared the outcomes of 13 consecutive deliveries following LAGB surgery with outcomes of 414 consecutive patients who were obese (BMI ≥30) who delivered at the same practice between 2004 and 2006. Gestational diabetes (0% vs 22.1%, $P<.05$) and preeclampsia (0% vs 3.1%, $P<.05$) were lower in the bariatric surgery group than in the obese comparison group, but there were no differences in pregnancy-induced hypertension or need for labor induction. Maternal weight gain was reduced in the surgical group (5.5 vs 7.1 kg, $P<.05$).

Three additional LAGB studies,[21-23] which compared outcomes to selected obese patients who did not undergo surgery or to historical presurgery pregnancies, also found lower rates of gestational diabetes, preeclampsia, and maternal weight gain, but in addition found lower rates of pregnancy-induced hypertension in the bariatric surgery group. One study[21] reported that outcome rates for the surgery group approached rates in the community. The findings were supported by 6 case series that reported low rates of these maternal outcomes in pregnancies following LAGB.[34-39]

Gastric Bypass. Two cohort studies reported on maternal outcomes following gastric bypass.[19,20] Both reported on consecutive deliveries following bariatric surgery in a single practice. Wax et al[19] compared outcome rates for the bariatric surgery group with a comparison group consisting of the next 2 consecutive deliveries after the index case, matched for age and prior cesarean delivery. Patel et al[20] compared outcomes following surgery with a comparison group consisting of the 5 consecutive nonsurgical women who delivered before and the 5 consecutive nonsurgical women who delivered after each index case, stratifying by obesity. Wax et al[19] found a higher risk of pregnancy-induced hypertension in the bariatric surgery group compared with the nonsurgical comparison group. However, women with bariatric surgery were more obese than the comparison group, with 68% and 26%, respectively, having a BMI of 30 or higher ($P<.001$). There were no differences between the 2 groups in rates of gestational diabetes or weight gain. Patel et al[20] found that rates of gestational diabetes, preeclampsia, and pregnancy-induced hypertension did not differ between the bariatric surgery and comparison cohorts.

Two additional studies compared outcomes after gastric bypass surgery with presurgery pregnancies from the same patients or with patients matched for presurgery weight, parity, and year of delivery.[24,25] For all outcomes, these studies found no differences or found lower outcome rates in the bariatric surgery group compared with the control group.

Among case series on gastric bypass, only 1 study[40] reported data on the maternal outcomes of interest. This study identified no occurrences of gestational diabetes (n=100).

VBG and BPD. Two studies of maternal outcomes after VBG procedures found similar results to the cohort studies involving LAGB and gastric bypass procedures. One study[28] reported low rates of gestational diabetes, pregnancy-induced hypertension, and preeclampsia among the surgery cohort and the other study[27] reported a lower rate of gestational diabetes in comparison with presurgery historical pregnancies. One cohort study[29] on BPD reported a lower pregnancy-induced hypertension rate among patients who had surgery.

Mixed Procedures. Two studies[31,32] assessed pregnancy outcomes following a variety of bariatric procedures. One study[31] compared pregnancy outcomes for 298 patients who underwent bariatric surgery with community rates and found a higher rate of gestational diabetes in the surgery group (9.4% vs 5.0%, $P<.001$), but no difference in preeclampsia. Importantly, obesity was more prevalent among patients who had surgery compared with the community (10.7% vs 1.2%, $P<.001$). A second study[32] found lower rates of gestational diabetes, preeclampsia, and pregnancy-induced hypertension following surgery.

In conclusion, 3 matched cohort studies found that adverse maternal outcomes in pregnancies following LAGB and gastric bypass may be lower than those outcomes of obese comparison groups and may approach rates in patients who are not obese. Additional cohort studies and case series studies support these findings. Few studies have assessed pregnancy outcome rates after BPD.

Rates of Cesarean Delivery and Other Delivery Complications. Thirteen studies[18-20,22-25,27-31,33] compared cesarean delivery rates following bariatric surgery with a comparison group

Table 1. Observational Studies on Maternal Pregnancy Outcomes Following Bariatric Surgery

	Inclusion Criteria		% of Patients							
			Gestational Diabetes		Preeclampsia[a]		Pregnancy-Induced Hypertension		Cesarean Delivery	
Source and Surgery Type	Bariatric Surgery	Comparison (Control)	Bariatric Surgery	Control	Bariatric Surgery	Control	Bariatric Surgery	Control	Bariatric Surgery	Control
LAGB										
Ducarme et al,[18] 2007	13 Consecutive pregnancies (delivered 2004-2006)	414 Obese (BMI ≥30) consecutive controls (delivered 2004-2006)	0	22.1[b]	0	3.1[b]	7.7	8.2	15.3	34.4[c]
Dixon et al,[21] 2005	79 Consecutive first postoperative pregnancies (1995-2003)	40 Consecutive penultimate preoperative pregnancies	6.3	15	5	28[b]	10	45[b]	NR	NR
		79 Controls matched for parity, age, and BMI		19[b]		25[b]		38[b]		
		61 000 Community controls		5.5		NR		10-13		
Dixon et al,[22] 2001[d]	Selected sample of 22 pregnancies	264 Preoperative pregnancies	4.5	9.4	NR	NR	4.5	37[b]	13.6	30
Skull et al,[23] 2004	49 Pregnancies from consecutive patients	31 Consecutive historical preoperative pregnancies	8	27[b]	2	9.6[e]	8.1	22.5[e]	28.5	16.1
Gastric bypass										
Wax et al,[19] 2008	38 Consecutive patients	76 Controls (next 2 deliveries after index case), matched for age and prior cesarean	5.3	4.0	NR	NR	29.0	7.9[b]	65.8	64.5
Patel et al,[20] 2008	26 Consecutive pregnancies (delivered 2003-2006)	254 Controls (5 deliveries before and after index case 2003-2006)	3.8		3.8		3.8		61.5	
		188 nonobese		1.6		3.7		3.7		36.2[a]
		39 obese		5.1		7.7		2.6		46.5
		27 severely obese		14.8		7.4		7.4		43.5
Richards et al,[24] 1987	57 Pregnancies from 243 of 580 surveys (1979-1983)	57 Preoperative pregnancies from same 243 surveys, matched on weight, parity, and year	5.3	10.5	NR	NR	8.8	45.6[f,g]	24.6	15.8
Wittgrove et al,[25] 1998	17 Selected patients identified through bariatric newsletter	Preoperative historical pregnancies from the same 17 patients	0	23.5[b]	NR	NR	0	41[g]	35.3	35.3
Landsberger et al,[26] 2006[h]	19 Patients (delivered 2004-2006)	38 Controls	15.8		Trend toward preeclampsia in bariatric cohort (*P* = .051) but no data provided		No difference noted (data not given)		No difference noted (data not given)	
		19 matched for preoperative BMI		42.1						
		19 matched for postoperative BMI (2004-2006)		21.1						
VBG										
Bilenka et al,[27] 1995	14 Deliveries (1985-1990)	Preoperative historical deliveries (n = 18) from the same 9 patients	0	16.7[i]	7.1	5.6	15.3	5.6	0	5.6
VBG/mixed										
Deitel et al,[28] 1988	7 Selected patients (9 pregnancies)	Selected sample of 86 preoperative patients (274 pregnancies)	0	7[b]	0	12.8[g]	0	26.7[g]	0	11.2 of pregnancies[c]
BPD										
Friedman et al,[29] 1995	152 Consecutive pregnancies	77 Preoperative historical pregnancies	NR	3.9	NR	9.1	0.7	2.6	44	31.2[b]
Kral et al,[30] 2006	79 Children from primigravid postoperative pregnancies	34 Children from primigravid preoperative pregnancies	NR	NR	NR	NR	NR	NR	19	34

(continued)

Table 1. Observational Studies on Maternal Pregnancy Outcomes Following Bariatric Surgery (continued)

	Inclusion Criteria		% of Patients							
			Gestational Diabetes		Preeclampsia[a]		Pregnancy-Induced Hypertension		Cesarean Delivery	
Source and Surgery Type	Bariatric Surgery	Comparison (Control)	Bariatric Surgery	Control	Bariatric Surgery	Control	Bariatric Surgery	Control	Bariatric Surgery	Control
Bariatric mix										
Sheiner et al,[31] 2004	298 Consecutive deliveries (1988-2002)	158 912 Consecutive population deliveries (1988-2002)	9.4	5.0[g]	5.7	4.7	5.4[f]	1.7[f]	25.2	12.2[g]
Bariatric										
Weintraub et al,[32] 2007[h]	507 Deliveries (1988-2006)	301 Preoperative deliveries (1988-2006)	11.0	17.3[f]	1.0	4.0[g]	11.2	23.6[f,g]	NR	NR
Heinzen et al,[33] 2006[h]	22 Consecutive deliveries (1999-2006)	700 Computer-generated random control delivieries	No difference noted (data not given)		No difference noted (data not given)		NR	NR	No difference noted (data not given)	

Abbreviations: BMI, body mass index, calculated as weight in kilograms divided by height in meters squared; BPD, biliopancreatic diversion/duodenal switch; LAGB, laparoscopic adjustable gastric banding; NR, not reported; VBG, vertical-banded gastroplasty.
[a] Included eclampsia, if it was also reported.
[b] $P < .05$.
[c] $P < .01$.
[d] Dixon et al[22] reported on 22 pregnancies that may be included in the other Dixon et al[21] article, which compared postoperative pregnancies with all pregnancies in the state of Victoria (61 000) and only had information on pregnancy-induced hypertension and gestational diabetes (not included in Table).
[e] $P = .06$.
[f] Included chronic hypertension.
[g] $P < .001$.
[h] Abstract available only.
[i] $P = .07$.

(eg, nonobese women, obese women, presurgery pregnancies, or the general population). Rates ranged from 0% to 65.8% for postsurgery pregnancies and from 5.6% to 64.5% for pregnancies in comparison groups (Table 1). Some studies reported lower rates of cesarean delivery after surgery, whereas other studies reported higher rates or no difference.

The 3 cohort studies did not report consistent findings. Ducarme et al[18] reported an overall cesarean delivery rate after LAGB procedures that was half that of obese nonsurgical comparisons and a 0% cesarean delivery rate before start of labor. The 2 gastric bypass cohort studies found high rates of cesarean delivery in the surgery groups (>60%) that did not differ from obese comparison groups, but exceeded those rates of the nonobese groups. Cesarean delivery rates varied in the other cohort studies (Table 1). Based on these data, bariatric surgery does not appear to have a strong relationship with cesarean delivery rates.

Only 2 studies specifically reported on rates of delivery complications, such as blood loss or operative injury. These studies[18,19] found no differences in delivery complications between surgery patients and comparison groups.

Neonatal Outcomes

Fourteen studies compared neonatal outcomes following bariatric surgery with a comparison group. The 4 most commonly noted outcomes were premature delivery (<37 weeks' gestation), low birth weight (<2.5 kg), macrosomia (>4.0 or >4.5 kg), and perinatal mortality (TABLE 2).*

Laparoscopic Adjustable Gastric Banding. Ducarme et al[18] found no difference in preterm birth rates or mean birth weight after LAGB vs obese comparison group. However, rates of low birth weight (7.7% vs 10.6%, $P<.05$) and macrosomia (7.7% vs 14.6%, $P<.05$) were lower among patients who had surgery.

Another study[21] found that macrosomia rates were lower among patients who had bariatric surgery than among control patients who were obese (11.4% vs 17.7%) and approached rates in the community (11.8%). Six case series[34-39] on LAGB procedures (n=162) found low rates of neonatal complications, consistent with findings in the matched cohort study.

Gastric Bypass. In 2 matched cohort studies,[19,20] patients who underwent gastric bypass showed no differences in premature delivery or low birth weight compared with patients who were not obese. In both studies, there were no cases of macrosomia in the patients who had surgery, whereas rates were 2.6% and 4.3% in the nonobese comparisons (P=not reported [1 study] and $P=.28$ [1 study]). Other cohort studies[24,25] of gastric bypass found lower mean birth weight and lower macrosomia rates in the pregnancies after surgery compared with rates in the obese comparison groups.

Relatively low neonatal complication rates were also reported in 8 case series of pregnancy following gastric bypass (approximately 300 pregnancies).[40,42-48] However, 2 studies[43,44] reported higher than expected rates of neural tube defects (1 study[44] described 4 pregnancies and the other study[43] 3 pregnancies, of a total 110 pregnancies, resulting in infants with neural tube defects). Mothers in these cases were reported to be nonadherent with recommended vitamin supplementation.

*References 18-21, 23-26, 28, 29, 31-33, 41.

Table 2. Observational Studies on Neonatal Outcomes Following Bariatric Surgery[a]

	Inclusion Criteria		% of Patients							
			Premature Delivery (<37 wk)		Low Birth Weight (<2.5 kg)		Macrosomia (>4.0 or >4.5 kg)		Perinatal Mortality	
Source and Surgery Type	Bariatric Surgery	Comparison (Control)	Bariatric Surgery	Control	Bariatric Surgery	Control	Bariatric Surgery	Control	Bariatric Surgery	Control
LAGB										
Ducarme et al,[18] 2007	13 Consecutive pregnancies (delivered 2004-2006)	414 Obese (BMI ≥30) consecutive controls (delivered 2004-2006)	7.7	7.1	7.7	10.6[b]	7.7	14.6[b]	NR	NR
Dixon et al,[21] 2005[c]	79 Consecutive first postoperative pregnancies (1995-2003)	40 Consecutive penultimate preoperative pregnancies	6.3	NR	6.3	NR	11.4	NR	1.3	0
		79 From obese women matched for parity, age, and BMI		12.7[d,e]		8.9		17.7[d]		
		61 000 Community controls		7.8		6.9		11.8		
Gastric bypass										
Wax et al,[19] 2008	38 Consecutive patients	76 Controls (next 2 deliveries after index case), matched for age and prior cesarean	26.3	22.4	7.7	9.0	0	2.6	NR	NR
Patel et al,[20] 2008	26 Consecutive pregnancies (delivered 2003-2006)	254 Controls (5 deliveries before and after index case 2003-2006)	26.9	20.2	NR	NR	0		NR	NR
		188 nonobese						4.3		
		39 obese		17.9				7.7		
		27 severely obese		25.9				18.5[b]		
Richards et al,[24] 1987[f]	57 Pregnancies from 243 of 580 surveys (1979-1983)	57 Preoperative pregnancies from same 243 surveys, matched on weight, parity, and year	12.3	7.0	NR	NR	15.8	36.8[b]	3.5	3.5
Wittgrove et al,[25] 1998	17 Selected patients identified through bariatric newsletter	Preoperative historical pregnancies from the same 17 patients	NR	NR	NR	NR	5.6	30.4[b]	0	0
BPD										
Marceau et al,[41] 2004	162 Full-term pregnancies from 783 questionnaires	1236 Full-term preoperative pregnancies	13.6	16.7	27.4	NR	7.7	34.8[g]	0.6	1.0
Friedman et al,[29] 1995	152 Consecutive pregnancies	77 Preoperative historical pregnancies	15.3	NR	NR	NR	NR	NR	2.6	2.6
Bariatric mix										
Sheiner et al,[31] 2004	298 Consecutive deliveries (1988-2002)	158 912 Consecutive population deliveries (1988-2002)	NR	NR	NR	NR	9.4	4.6[g]	0.3	1.5
VBG/mix										
Deitel et al,[28] 1988	7 Selected patients	Selected sample of 86 preoperative patients	NR	NR	NR	NR	NR	NR	0	0
Bariatric										
Weintraub et al,[32] 2007	507 Deliveries (1988-2006)	301 Preoperative deliveries (1988-2006)	NR	NR	NR	NR	3.2	7.6[h]	NR	NR

Abbreviations: BMI, body mass index, calculated as weight in kilograms divided by height in meters squared; BPD, biliopancreatic diversion/duodenal switch; LAGB, laparoscopic adjustable gastric banding; NR, not reported; VBG, vertical-banded gastroplasty.

[a] Three additional studies reported only mean birth weight; therefore, data were not included in the table (Skull et al,[23] Heinzen et al,[33] Landsberger et al[26]), with the latter 2 reported only in abstract form. Landsberger et al[26] reported no difference in preterm delivery or perinatal complications.

[b] $P < .05$.

[c] An additional study by Dixon et al[22] was not included, which reported on 22 pregnancies; no comparison group data were provided in that article.

[d] Compared with obese-matched patients rather than historical pregnancies.

[e] $P = .08$.

[f] Large for gestational age.

[g] $P < .001$.

[h] $P < .005$.

Biliopancreatic Diversion. Neonatal outcomes following BPD were assessed in 2 cohort studies (with >150 pregnancies)[29,41] (Table 2) and 4 case series.[49-52] One cohort study[41] found no difference in preterm birth rates, but lower mean birth weight and macrosomia rates in the surgery group were found compared with controls who were obese (3 kg vs 3.5 kg, $P<.001$; and 7.7% vs 34.8%, $P<.001$, respectively). The other study[29] found that after BPD, 22 of the singleton pregnancies (15.3%) were preterm deliveries compared with US estimates of 12.8% in 2005.[53]

A number of studies reported miscarriage and perinatal mortality rates following BPD.[29,41,49-52] In 1 cohort study (n=152), miscarriage rates were approximately 20% before and after surgery and perinatal mortality was 2.6% for both groups.[29] In another cohort study (n=251),[41] miscarriage rates were 21.6% before bariatric surgery vs 26.0% after bariatric surgery. The 4 case series[49-52] included 108 pregnancies following BPD.

Mixed Procedures. A study[31] that compared pregnancy outcomes between 298 patients who underwent a variety of bariatric procedures and a nonobese comparison group found higher labor induction rates (23.8% vs 10.9%, $P<.001$), mean birth weights ($P=.02$), and macrosomia ($P<.001$), and no difference in perinatal mortality among women with history of bariatric procedures.

Overall, following LAGB and gastric bypass procedures, there is no strong evidence that adverse neonatal outcome rates are higher compared with obese groups. Following BPD, adverse neonatal outcomes may be lower; however, miscarriage rates may be higher.

Table 3. Observational Studies of Nutritional Outcomes in Pregnancy Following Bariatric Surgery

Source and Surgery Type	No. of Pregnancies After Surgery	Selection Criteria	Findings
LAGB			
Dixon et al,[21] 2005	79	Selected sample (consecutive pregnancies)	No adverse nutritional events; 84% adherent with vitamin supplementation
Gastric bypass			
Patel et al,[20] 2008	26	Selected sample (consecutive pregnancies)	11.5% Had anemia treated with parenteral iron, anemia was found to be 1.1% in nonobese controls (*P* = .001); adherence with vitamin supplementation unknown
Wittgrove et al,[25] 1998	36	Volunteers from media advertisement	No clinically significant anemia; adherence with vitamin supplementation unknown
Martin et al,[43] 1988	110	Survey and review of records to identify infants with neural tube defects	3 Women had infants with neural tube defects; all were nonadherent with vitamin supplementation
Haddow et al,[44] 1986	3	Not reported	3 Women had infants with neural tube defects; all were nonadherent with vitamin supplementation
Printen and Scott,[45] 1982	54	Not reported	4.4% Required parenteral iron; adherence with vitamin supplementation unknown
Dao et al,[47] 2006	34	Selected sample	1 Woman had mild anemia that resolved with supplementation; adherence with vitamin supplementation unknown
BPD			
Friedman et al,[29] 1995	152	Consecutive patients	21% Required parenteral nutrition; all other patients received "usual supplementation"
Marceau et al,[41] 2004	166	Survey of patients and review of prenatal records	4 Women required parenteral nutrition; unknown adherence with vitamin supplementation
Cools et al,[49] 2006	9	Not reported	4 Women had iron deficiency requiring transfusion or supplements; 1 also required parenteral nutrition; 3 were adherent with vitamin supplementation and 5 were not; unknown whether 1 was adherent
Gerrits et al,[50] 2003	4	Study of contraception following BPD; reviewed 4 unplanned pregnancies	1 Woman had anemia despite iron supplementation; 1 had unspecified vitamin deficiency while not taking any supplementation; remaining 2 were adherent with vitamin supplementation
Adami et al,[51] 1992	64	Not reported	20% Required parenteral nutrition; adherence with vitamin supplementation unknown
Friedman et al,[52] 1989	48	Not reported	15% Required inpatient parenteral nutrition and 17% required outpatient parenteral nutrition; all other patients received "usual supplementation"

Abbreviations: BPD, biliopancreatic diversion/duodenal switch; LAGB, laparoscopic adjustable gastric banding.

Nutritional Deficiencies

Dietary guidelines recommend supplementation with multivitamins and iron following bariatric surgery.[54,55] Observational studies evaluating pregnancy after LAGB or gastric bypass have shown minimal evidence of nutritional adverse events; however, most monitored supplement adherence. Of 22 studies that addressed the issues of nutritional deficiencies, 13 were comparison studies or case series (TABLE 3) and 9 were case reports.

Laparoscopic Adjustable Gastric Banding. One study[21] of women who became pregnant after LAGB reported no nutritional problems; 84% of the 79 pregnant women reported adherence with supplementation. However, among 4 studies,[23,35,37,38] approximately 19% of pregnant women had their adjustable LAGB deflated or removed for various reasons, including nausea and vomiting and patient preference.

Gastric Bypass. Gastric bypass was associated with few nutritional adverse outcomes during pregnancy (Table 3). Four studies[20,25,45,47] reported low rates of anemia, ranging from 0% to 11%. Two other studies[43,44] reported neural tube defects in pregnancies (6 neonates) following gastric bypass; however, none of the mothers were adherent with supplements. Four case reports[56-59] following gastric bypass reported nutritional deficiencies (2 had adherence and 2 did not have adherence with supplementation).

Biliopancreatic Diversion. Observational studies[29,41,51,52] show that parenteral nutrition is used in approximately 20% of pregnancies following BPD. Several small case series of pregnancies following BPD reported nutritional deficiencies among women taking nutritional supplements, those not taking supplements, and some in whom adherence was unclear.[49,50,60-62]

There are few studies of adverse nutritional outcomes in pregnancies following LAGB or gastric bypass surgeries when nutritional supplementation was maintained. Severe nutritional deficiencies requiring parenteral nutrition have been reported in pregnancies following BPD. Many, but not all, of the studies attributed the deficiency to nonadherence. Of concern were several studies of neural tube defects, particularly in neonates of women who had undergone gastric bypass and been nonadherent. However, these studies were not designed to specifically assess nutritional outcomes.

Bariatric Surgery and Fertility. We identified 6 studies[27,28,31,41,63,64] that addressed fertility outcomes in patients after bariatric surgery and most of these compared pregnancy rates before and after surgery (TABLE 4). Three small studies[27,28,41] reported improvements in fertility and 1 study[63] noted no change.

One study (n=298) found that after bariatric surgery, the need for fertility treatment in women was low (6.7%) but exceeded that of the community (2.3%, $P < .001$).[31] Similar results were found for patients after surgery with gestational diabetes compared with a nonsurgery control population with gestational diabetes.[64] Five additional case series (n=21 to 48)[22,25,35,37,52] found that infertility rates before surgery ranged from 15% to 44%.

Six studies[28,50,63,65-67] found evidence of normalization of hormones and menstrual cycles and lessening of polycystic ovarian syndrome following bariatric surgery. One study[65] prospectively followed up 17 women who had BPD or gastic bypass surgery and found decreases in hirsutism, testosterone, androstenedione, and dehydroepiandrosterone sulfate and also found normalization of menstrual cycles, ovulation, or both in all women. A prospective case series[50] of women before and after BPD surgery demonstrated normalization of hormones. The postsurgery normalization of menstrual cycles was observed in a cohort study of 109 women ($P < .001$).[28] A retrospective survey[63] reported that menstrual cycles normalized in 71.4% (95% confidence interval, 62.3%-80.5%) of 98 previously anovulatory women and that resumption of ovulation was associated with greater weight loss following surgery. Another study[66] showed resolution of polycystic ovarian syndrome following gastric bypass surgery: all 24 women resumed normal menstrual cycles, 5 conceived without clomiphene, and hirsutism resolved in more than 50%. A study[67] following VBG surgery (n=38) found improvements in hormone levels and normalization of menstrual cycles among all 5 women with abnormal cycles.

Table 4. Observational Studies Reporting Fertility Outcomes for Patients Following Bariatric Surgery

Source and Surgery Type	Inclusion Criteria: Bariatric Surgery	Inclusion Criteria: Comparison	Findings
Bariatric mix			
Sheiner et al,[31] 2004	298 Consecutive postoperative deliveries (1988-2002)	158 912 Consecutive general population deliveries (1988-2002)	6.7% Required fertility treatment after surgery vs 2.3% of population ($P < .001$)
Sheiner et al,[64] 2006[b]	28 Postoperative deliveries in women with gestational diabetes	7986 Deliveries in women with gestational diabetes	21.4% after surgery with gestational diabetes required fertility treatment vs 5.5% of patients from population with gestational diabetes ($P < .001$
Gastric bypass/mixed			
Teitelman et al,[63] 2006	Postoperative data on 195 questionnaires (51% response)	Preoperative data on 195 questionnaire responders	17.5% With menstrual irregularities after surgery vs 49.5% before ($P < .001$); no significant difference in fertility medication use[a]
VBG			
Bilenka et al,[27] 1995	14 Postoperative deliveries	18 Preoperative deliveries	11.1% Received fertility treatment after surgery vs 83% (5/6) before ($P < .001$)[a]
VBG/mix			
Deitel et al,[28] 1988	Selected sample of 7 women with postoperative deliveries	Selected sample of 86 women with preoperative deliveries	88.9% Able to get pregnant after surgery vs 25.2% before ($P < .001$)[a]
BPD			
Marceau et al,[41] 2004	162 Postoperative pregnancies from 783 patient questionnaires (85% response)	1236 Full-term preoperative pregnancies	46.9% (15/32) who were unable to get pregnant before surgery were able to get pregnant after surgery[a]

Abbreviations: BPD, biliopancreatic diversion/duodenal switch; LAGB, laparoscopic adjustable gastric banding; VBG, vertical-banded gastroplasty.
[a] May have selection bias because it is unknown how many patients overall desired and attempted pregnancy after surgery.
[b] Subset of Sheiner et al.[31]

Most observations on fertility following bariatric surgery lack complete data on the total number of women attempting to get pregnant and pregnancy rates. Most studies present convenience samples of women who were able to get pregnant, in whom presurgery fertility histories were available. With these significant limitations in mind, data suggest that surgery may have a beneficial influence on fertility, which is supported by the normalization of hormones in polycystic ovarian syndrome and correction of abnormal menstrual cycles.

Contraceptive Use. No randomized trials have assessed the efficacy of contraception after bariatric surgery. Theoretical concerns exist about absorption of oral contraceptive pills in patients following a malabsorptive procedure, such as BPD. One case series[50] identified 2 failures for oral contraceptive pills out of 40 women after BPD surgery. No firm conclusions can be drawn about the effectiveness of contraceptive methods following bariatric surgery.

Evidence on Time to Delay of Pregnancy After Bariatric Surgery

We identified 5 studies comparing pregnancy outcomes within the first year up to 18 months following surgery with later pregnancies. One study[42] included 18 women with 21 successful pregnancies after gastric bypass surgery. Of these women, 10 conceived within 1 year after surgery. No differences were found in rates of cesarean delivery, delivery complications, low birth weight, or congenital abnormalities. Another study[47] found no differences in outcomes between pregnancies within the first year following gastric bypass surgery vs pregnancies occurring more than 1 year after surgery. In a study comparing 20 pregnancies in which conception occurred within the first year after LAGB,[21] maternal weight gain was lower in these early postsurgery pregnancies, birth weight was unchanged, and there were no differences in pregnancy complications or preterm deliveries. Another study[68] found a higher spontaneous abortion rate among pregnancies occurring within 18 months of having BPD surgery compared with those pregnancies occurring after 18 months of having BPD surgery (31% vs 18%). In a matched cohort study, Patel et al[20] stratified the postoperative cohort of 26 patients by time to conception from surgery and found that 4 women (15.4%) were pregnant within the first year, 12 (46.1%) were pregnant between 13 and 24 months, and 10 (38.5%) became pregnant after more than 2 years. Early pregnancies were associated with more preterm deliveries (50% for <12 months, 25% for 13-24 months, and 20% for ≥ 24 months). A study that investigated pregnancies within 2 years after gastric bypass surgery found a high rate of premature births (18%), but this study included no comparison group.[45] A study of pregnancies within 2 years of LAGB surgery found spontaneous abortion rates to be 29%.[36]

In conclusion, few data are available to support recommendations regarding the ideal timing for pregnancies following surgery. However, there are reports of successful pregnancies within 1 or 2 years of surgery.

Surgical Complications in Pregnancies Following Bariatric Surgery

We identified 20 reports of complications requiring surgical intervention during pregnancy following bariatric surgery. Maternal complications included 14 bowel obstructions (11 internal hernias), 1 gastric ulcer, 4 band events, and 1 staple-line stricture.[20,23,69-83] Gestational age at adverse event ranged from 13 to 37 weeks (median, 26 weeks). Most women presented with nonspecific abdominal complaints and delays often occurred before therapeutic intervention. In 7 of 20 cases (35%), an emergent cesarean delivery or premature rupture of membranes occurred. Five neonates died (25%) and 10 were delivered full-term (50%). There were 3 maternal deaths (15%). The case reports indicate the potential for complications in pregnancies following bariatric surgery, including maternal and fetal death.

COMMENT

More than 150 000 women of reproductive age underwent bariatric procedures in the most recent 3 years for which inpatient data are available. This figure is likely an underestimate because many patients undergo outpatient bariatric surgical procedures (eg, LAGB surgery) that would not have been reported in the Nationwide Inpatient Sample. A growing number of women of child-bearing age have undergone these procedures and need information and guidance about fertility, pregnancy, and contraception.

The available evidence suggests that risks for maternal complications, such as gestational diabetes and preeclampsia, may be lower following surgically induced weight loss than the risks in obese women and may approach community rates. Similarly, neonatal complications, such as premature delivery and low birth weight, may be lower in pregnancies following bariatric surgery. Results from large cohorts of consecutive patients with pregnancies are needed to confirm these findings. The effect of bariatric surgery on need for cesarean delivery is unclear as reported rates before and after surgery vary widely between studies. Nutritional problems during pregnancy following LAGB or gastric bypass surgeries appear uncommon and many are attributed to supplement nonadherence. Studies of consecutive patients that systematically monitor adherence and nutritional status are needed. The relationship of bariatric surgery to fertility has not been well studied. Reports of normalization of sex hormones, menstrual irregularities, and improvement in polycystic ovarian syndrome following surgery suggest that fertility may improve, which would be consistent with that observed in obese women after nonsurgically induced weight loss. However, most of these studies may have selection bias, limiting their ability to reach valid conclusions. Although rare, complications of bariatric surgery can manifest during pregnancy. The most commonly reported complication is internal hernia causing bowel compromise. There is no strong evidence to guide how long to delay pregnancy following bariatric surgery. The typical recommended period is 1 year, coinciding with the end of the period of most rapid weight loss. There is no convincing evidence to support or refute concerns about the use of oral contraceptive pills following bariatric surgery.

Our review is limited by the quality of the original studies. Three matched cohort studies assessed consecutive patients and compared these with concurrent control groups and provided the main evidence in support of our conclusions. However, sample sizes were modest (77 surgical cases and 744 comparison controls) and there may have been differences in women electing to undergo surgery compared with women who did not have surgery. Because randomized controlled trials will not be feasible for assessing pregnancy outcomes, these types of studies represent the best available evidence for assessing the effect of surgically induced weight loss on future pregnancies. However, inherent limitations in the identified studies preclude us from drawing strong conclusions. Some of these clinical questions addressed in our review, such as optimal contraception, will be best answered by randomized clinical trials or prospective cohort studies. Because clinicians must still make decisions regarding these patients, we assessed the best evidence available in an attempt to help guide clinicians.

Research is needed to better delineate the extent to which surgery and subsequent weight loss improve fertility and pregnancy outcomes. Optimizing success for contraception and producing healthy neonates following surgery will require a multidisciplinary effort by surgeons, primary care physicians, reproductive fertility specialists, obstetricians, and patients.

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Study concept and design: Maggard, Li, Maglione, Hilton, Santry, Livingston, Shekelle.
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Disclaimer: The authors of this article are responsible for its content. Statements in the article should not be construed as endorsement by the Agency for Healthcare Research and Quality or the US Department of Health and Human Services. All data used for this study are accessible for review.
Also Available: A more detailed clinical review of pregnancy and fertility following bariatric surgery will be available at http://www.ahrq.gov/downloads/pub/evidence/pdf/bariatricrep/barirep.pdf.

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