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The Risk of Adverse Pregnancy Outcomes Following Nonobstetric Surgery During Pregnancy

Estimates From a Retrospective Cohort Study of 6.5 Million Pregnancies

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Objective: The aim of this study was to estimate the risk of adverse birth outcomes for women who underwent nonobstetric surgery during pregnancy compared with those who did not.

Background: Previous research suggests that nonobstetric surgery occurs during 1% to 2% of pregnancies. However, there is limited evidence quantifying risks to the mother or pregnancy of such surgery.

Methods: We examined maternity admissions using hospital administrative data collected between April 1, 2002, and March 31, 2012, and identified pregnancies wherein nonobstetric surgery occurred. We used logistic regression models to determine the adjusted relative risk, attributable risk, and number needed to harm of nonobstetric surgical procedures for adverse birth outcomes.

Results: We identified 6,486,280 pregnancies. In 47,628 of these pregnancies, nonobstetric surgery had occurred. We found that nonobstetric surgery during pregnancy was associated with a higher risk of adverse birth outcomes, although the attributable risk was generally low. We estimated that every 287 surgical operations were associated with 1 additional stillbirth, every 31 operations associated with 1 additional preterm delivery, every 39 operations associated with 1 additional low birth weight baby, every 25 operations associated with 1 additional caesarean section, and every 50 operations associated with 1 additional long inpatient stay.

Conclusions: Although we have no means of disentangling the effect of the surgery from the effect of the underlying condition, we found that the risk associated with nonobstetric surgery was relatively low, confirming that surgical procedures during pregnancy are generally safe. We believe that our findings improve upon previous research, and are useful reference points for any discussion of risk with prospective patients.

Keywords: complications, obstetric, pregnancy, safety, surgery

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Traditional teaching states that there is an increased risk of miscarriage, stillbirth, and preterm labor when a pregnant woman undergoes surgery under general anesthesia during pregnancy.[1] This risk has however never been quantified and such risks may have decreased with the use of modern anesthetic agents and techniques. At present, when counseling a pregnant woman on this risk, the information provided is not robustly evidence-based.

Previous research suggests that 1% to 2 % of women undergo nonobstetric surgery during pregnancy,[2] common operations being appendicectomy, cancer surgery, and orthopedic procedures. Research has also suggested that nonobstetric surgery during pregnancy is associated with adverse birth outcomes: a Canadian study of 2565 pregnant women reported an increased risk of spontaneous abortion after a general anesthetic [relative risk (RR) = 1.58, 95% confidence interval (95% CI) 1.19–2.09];[3] and a Swedish registry study showed associations between nonobstetric operations during pregnancy and low birth weight.[4] A systematic review brought these and many smaller studies together.[5] In this analysis of 54 papers dominated by abdominal surgery, no association was shown between nonobstetric surgery and major birth defects, but strong associations were observed between acute appendicitis with peritonitis and fetal loss. However, much of the available evidence was between 20 and 40 years old and therefore unlikely to be representative of the current situation; studies were generally small and poorly controlled and overall gave conflicting results.

We aimed to estimate the risk of adverse birth outcomes, including spontaneous abortion associated with hospitalization (miscarriage), stillbirth, preterm delivery, low birth weight, caesarean section, and maternal death, for women who underwent nonobstetric surgery during pregnancy in England compared with those who did not, using more recent routinely collected hospital administrative data.

METHODS

We used the Hospital Episode Statistics (HES) database, which includes records of all admissions to English NHS hospital trusts. Each record contains data on patient demographics (eg, age, ethnicity, and socioeconomic deprivation based on postcode of residence), the episode of care (eg, hospital name, date of admission, and discharge), and clinical information.[6,7] Diagnoses for each patient are recorded using the International Classification of Diseases, 10th edition (ICD-10). Procedures performed during an episode are coded using the Office of Population, Censuses, and Surveys Classification of Surgical Operations and Procedures, 4th revision (OPCS).[8] Each episode relating to the delivery of a baby contains details about the obstetric history, labor, and delivery (eg, parity, mode of delivery, gestational age, birth weight) in supplementary data fields known as the HES ''maternity tail.'' In HES, each patient is assigned a unique identifier (HESID). This makes it possible to link historical medical records. We used all records collected between April 2002 and March 2012 inclusive. We searched for pregnancy records with procedure (OPCS 4) codes or ''maternity tail'' fields relating to delivery or with diagnosis (ICD-10) codes

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relating to spontaneous abortion associated with hospitalization. We restricted our sample to women aged between 15 and 49 years.[9–12] If pregnancy ended in delivery, we estimated the beginning of pregnancy as admission day minus gestational age (if available) OR admission day minus 36 weeks (if gestational age not available, but diagnosis field indicates preterm delivery), OR admission day minus 40 weeks (otherwise). As there was no gestational age in the dataset on episodes that ended in spontaneous abortion, we looked back only 3 months for surgery to avoid inclusion of surgery occurring before pregnancy. Nonobstetric surgery during pregnancy was identified using a refined operating room procedure code list based on OPCS procedure codes defined in previous research.[13]

We determined 7 adverse birth outcomes based on both mothers' and infants' records. Spontaneous abortion associated with hospitalization was defined as a pregnancy episode for which one of the diagnoses was recorded as ICD-10 code of spontaneous abortion (O03) or other abortion (O05), or unspecified abortion (O06); this definition excluded planned surgical or medical termination of pregnancy. The definition is based on coding, but to all intents and purposes means miscarriage, and therefore, from now on, we will refer to it as miscarriage associated with hospitalization. Still birth was defined as a pregnancy episode for which one of the diagnoses was recorded as ICD-10 code of single or multiple births with all stillborn (Z31.1, Z37.4, Z37.7), multiple births with some stillborn (Z37.3, Z37.6), or birth status field in the maternity tail coded as "still birth." We defined preterm delivery as a pregnancy episode for which one of the diagnoses was recorded as ICD-10 code of preterm delivery (O60) or the length of the gestation field in the HES maternity tail was lower than 37 weeks. We classified birth weight into 3 groups: one or more new-born with low birth weight (<2500 g), all new-born weighing 2500 g or more, and unknown. We identified cesarean section as a pregnancy episode wherein codes indicated an elective (R17) or other (R18) cesarean delivery or cesarean hysterectomy (R25.1), or delivery method field in the maternity tail coded as "elective caesarean section" or "emergency caesarean section." Long inpatient stay was defined as the upper quartile of length of stay plus 1.5 times the interquartile range (with separate values for cesarean and vaginal delivery; 9.5 and 3.5 days, respectively).[14] Maternal death was defined as a delivery or miscarriage associated with a hospitalization episode with method of discharge field coded as a death within the same admission stay.

We adjusted the risk of all outcomes of interest for maternal age, socioeconomic deprivation (Carstairs quintile),[15] parity, previous cesarean section, previous emergency admission, comorbidities (Charlson score),[16] multiple gestation, operations on amniotic cavity (including amniocentesis, sampling of chorionic villus), obstetric surgery, and for the presence of cardiac disease, hypertension/preeclampsia, and gestational diabetes[17–24] (Supplement Table 1, http://links.lww.com/SLA/B89).

Statistical Analyses

We used the adjusted odds ratio (ORs) obtained directly from a logistic regression model to estimate the RRs and its 95% CIs of adverse birth outcomes in pregnancies wherein surgery occurred compared with pregnancies wherein surgery did not occur.[25,26] All pregnancy records were included in the analysis when miscarriage associated with hospitalization and maternal death were the outcomes of interest. For the remaining outcomes, only pregnancy records that ended in delivery were included. We used the logistic regression model to estimate the marginal probabilities of each outcome of interest (Austin's method).[27] This method overcomes the issue in studies of common outcomes wherein the OR can overestimate the RR. This permitted us to estimate the adjusted RR, the attributable risk (AR), and the number needed to harm (NNH).[28,29] The AR is the difference in risk between mothers undergoing nonobstetric surgery and all other mothers, and represents the additional risk experienced by mothers undergoing nonobstetric surgery, above and beyond the baseline risk. NNH is a measure that indicates how many patients on average need to be exposed to a risk factor to cause harm in an average of 1 patient who would not otherwise have been harmed. CIs for each measure of effect were estimated using a nonparametric bootstrap method. The endpoints of 95% CIs were defined as the 2.5th and 97.5th percentiles of that measured across the bootstrap samples.[30] We also independently examined adverse birth outcomes in the common group of procedures, and by trimester. The OPCS codes were grouped according to specialty in order to provide a framework for analysis that was clinically meaningful. Operations on the abdomen were placed in the "abdominal" group, but this was then subdivided into "laparoscopic," "open," and "appendix." "Orthopedic" was not only used for operations on bone and tendons but also for example carpal tunnel release and ganglion excision wherein the surgeon was not necessarily orthopedic. "ENT" procedures did not include head and neck cases or thyroid/parathyroid surgery, as they are coded separately under OPCS.

Sensitivity analyses were carried out to evaluate the potential effect of missing data in the stillbirth and low birth weight variables. All analyses were carried out with SAS 9.2 software package (SAS Institute, Cary, NC).

RESULTS

A total of 6,484,280 pregnancies were identified from the period April 2002 to March 2012. Two-thirds of study population were aged between 20 and 34 years (73.4%) and the majority were multiparous (55.5%) (Table 1). Twenty-seven percent of women were living in the most socio-economically deprived area. More than 10% of our population had an emergency admission to hospital a year before pregnancy and nearly 10% previously had a cesarean delivery.

Miscarriage associated with hospitalization occurred in 5.8% of these pregnancies. Among our cohort, there were more than 450,000 (7.5%) preterm deliveries and nearly 1.5 million (23.9%) elective or emergency cesarean deliveries. Two hundred thirty-five maternal deaths were identified and this corresponds to a maternal death rate of 4 per 100,000 (Table 2). We identified 47,628 pregnancies wherein nonobstetric surgery occurred (0.7% of all pregnancies).

The most common surgical group was abdominal (12,493, 26.2%) followed by dental (5365, 11.3), nail-skin (4762, 10.0), orthopedic (4563, 9.6%), ENT (3060, 6.4%), perianal (2977, 6.3%), and breast (1884, 4.0%) (Table 3). There were 3062 cases of appendicectomy and 1306 cases of cholecystectomy. Only 4% of all operations occurred in the same admission as the delivery or miscarriage associated with hospitalization. Furthermore, only 1.8% of miscarriage associated with hospitalization occurred in the same admission as the procedure. A closer examination of timing between delivery (or miscarriage) and surgery suggested that fewer than 6% of operations occurred within 1 week of the end of pregnancy.

After adjusting for potential confounders, the AR for miscarriage associated with hospitalization was 0.7% (95% CI 0.4–0.9) (NNH = 143), for still birth 0.4% (95% CI 0.3–0.4) (NNH = 287), for preterm delivery 3.2% (95% CI 2.9–3.4) (NNH = 31), for low birth weight 2.6% (95% CI 2.5–2.9) (NNH = 39), for cesarean section 4.0% (95% CI 3.6–4.5) (NNH = 25), and for long inpatient stay 2.0% (95% CI 1.7–2.4) (NNH = 50) in those women who had nonobstetric surgery compared with those who did not (Table 4). The AR for maternal death was 0.013% (95% CI 0.003–0.028) (NNH = 7692). Due to missing data, we carried out sensitivity analyses for

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TABLE 1. Characteristics of Risk Factors in the Study Population of Pregnancies in England in 2002–2012

Risk Factor	Frequency (%)		
	Total Pregnancies	Pregnancies Wherein Surgery did not Occur	Pregnancies Wherein Surgery Occurred
Total number of pregnancies	6,486,280 (100)	6,438,652 (100)	47,628 (100)
Maternal age, y*			
15–19	423,482 (6.5)	420,045 (6.5)	3437 (7.2)
20–24	1,228,398 (18.9)	1,217,961 (18.9)	10,437 (21.9)
25–29	1,702,845 (26.3)	1,690,140 (26.3)	12,705 (26.7)
30–34	1,830,026 (28.2)	1,817,982 (28.2)	12,044 (25.3)
35–39	1,049,786 (16.2)	1,042,638 (16.2)	7148 (15.0)
40 and over	251,743 (3.9)	249,886 (3.9)	1857 (3.9)
Carstairs quintile*	1,054,232 (16.3)	1,047,238 (16.3)	6994 (14.7)
1 = least deprived	1,064,704 (16.4)	1,057,376 (16.4)	7328 (15.4)
2	1,195,999 (18.4)	1,187,080 (18.4)	8919 (18.7)
3	1,371,638 (21.2)	1,360,905 (21.2)	10,733 (22.5)
4	1,754,815 (27.0)	1,741,297 (27.0)	13,518 (28.4)
5 = most deprived	44,892 (0.7)	44,756 (0.7)	136 (0.3)
6 = unknown	1,054,232 (16.3)	1,047,238 (16.3)	6994 (14.7)
Parity*			
Primiparous	2,888,248 (44.5)	2,867,468 (44.5)	20,780 (43.6)
Multiparous	3,598,032 (55.5)	3,571,184 (55.5)	26,848 (56.4)
Previous Cesarean deliveries* (Yes)	640,405 (9.8)	635,174 (9.8)	5231 (11.0)
Previous emergency admission*	672,946 (10.4)	664,019 (10.3)	8927 (18.7)
Charlson score* (prior pregnancy)			
0	6,375,029 (98.3)	6,329,356 (98.3)	45,673 (95.9)
1+	111,251 (1.7)	109,296 (1.7)	1955 (4.1)
Charlson score*			
0	6,254,984 (96.4)	6,210,332 (96.4)	44,652 (96.8)
1+	231,296 (3.6)	228,320 (3.6)	2976 (4.2)
Multiple gestation† (Yes)	70,758 (1.1)	70,198 (1.1)	560 (1.2)
Gestational diabetes* (Yes)	98,196 (1.5)	97,179 (1.5)	1017 (2.1)
Hypertension/preeclampsia* (Yes)	222,312 (3.4)	220,481 (3.4)	1831 (3.8)
Cardiac diseases* (Yes)	16,951 (0.3)	16,626 (0.3)	325 (0.7)
Other operations on amniotic cavity* (Yes)	32,491 (0.5)	32,214 (0.5)	277 (0.6)
Obstetric surgery* (Yes)	327,050 (5.0)	325,036 (5.1)	2014 (4.2)
Nonobstetric surgery	47,628 (0.7)	—	—

*Chi-square test $P < 0.05$.
†Chi-square test $P < 0.1$.

stillbirth and low birth weight, excluding missing values and found little difference in our results.

The AR of adverse birth outcomes (excluding maternal death) for women who underwent abdominal surgery was higher than women who did not have surgery during their pregnancy (Table 5). For miscarriage associated with hospitalization, the AR was 5.0% with an NNH of 20. Laparoscopic abdominal surgery was associated with a high AR for miscarriage (AR = 8.2%) and

TABLE 2. Outcomes of Pregnancies in England in 2002–2012

Outcome	Frequency (%)		
	Total Pregnancies	Pregnancies Wherein Surgery did not Occur	Pregnancies Wherein Surgery Occurred
Total number of pregnancies	6,486,280 (100)	6,438,652 (100)	47,628 (100)
Miscarriage associated with hospitalization	376,323 (5.8)	373, 203 (5.8)	3120 (6.6)
Stillbirth			
One or more still born	33,774 (0.6)	33,363 (0.6)	411 (0.9)
All live	5,996,017 (98.1)	5,952,658 (98.1)	43,359 (97.4)
Unknown	80,166 (1.3)	79,428 (1.3)	738 (1.7)
Preterm delivery	457,793 (7.5)	452,877 (7.5)	4916 (11.1)
Low birth weight			
One or more child with low birth weight (<2500 g)	342,631 (5.6)	338,800 (5.6)	3831 (8.6)
All children weight +2500 g	4,499,574 (73.6)	4,468,782 (73.7)	30,792 (69.2)
Unknown	1,267,752 (20.8)	125,7867 (20.7)	9885 (22.2)
Caesarean section	1,461,707 (23.9)	1,448,871 (23.9)	12,836 (28.8)
Long inpatient stay	578,709 (9.5)	573,471 (9.5)	5238 (11.8)
Maternal death	235 (0.004)	223 (0.003)	12 (0.025)

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TABLE 3. Total Number and Proportion of Common Procedure Groups

	Total Number	Proportion of Total (%)
Abdominal (any kind)	12,493	26.2
Appendicectomy	3062	6.4
Cholecystectomy	1306	2.7
Dental	5365	11.3
Nail-skin	4762	10.0
Orthopedic	4563	9.6
ENT	3060	6.4
Perianal	2977	6.2
Breast	1884	4.0
Cancer related	710	1.5

seemed to contribute to most of the risk for abdominal surgery, as open abdominal surgery alone was not associated with an increased risk of miscarriage (RR = 0.65, 95% CI 0.56–0.76). Nonabdominal surgical groups, including breast surgery, ENT, and orthopedic surgery, were also associated with significantly raised risk of some outcomes.

Approximately two-thirds of all abdominal operations were laparoscopic. Where gestational age was known, nearly 5 times as many abdominal operations in the first trimester were laparoscopic (3102) versus open (643). This ratio was reversed in the second trimester (606 laparoscopic vs 995 open), and by the third trimester, 2.5 times as many procedures were open (698) versus laparoscopic (284). Our analysis comparing outcomes between laparoscopic versus open abdominal surgery (RR = 3.82, 95% CI 3.29–4.41) shows an increased risk of a miscarriage associated with hospitalization for laparoscopic procedures.

The RR for preterm delivery and cesarean section for pregnancies wherein surgery occurred during the third trimester was 20% higher than the RR for pregnancies wherein surgery occurred during the first trimester (Fig. 1). There was a little change for the RR for long inpatient stay.

DISCUSSION

This is the first study to report the risk of adverse birth outcomes following nonobstetric surgery during pregnancy across NHS hospitals in England. We extracted data from nearly 6.5 million pregnancies between April 2002 and March 2012, 10 times the total in the published literature to date. Furthermore, our data are more recent and therefore better represent current outcomes.

Previous studies have tended to present relative measures of risk, which we also report in Tables 4 and 5. However, we believe that AR and NNHs are more useful measures of risk when attempting to gauge the additional risk of harm following nonobstetric surgery. However, to discuss how our results compare with other studies, we have drawn together the literature, and made some comparisons with published measures of association, including RR and ORs. For example, Duncan et al[3] found a higher RR (1.58) of spontaneous abortion associated with a general anesthetic in their 1986 Canadian study of 2565 pregnant women. For the purpose of comparison, we found a RR of 1.13 for miscarriage associated with hospitalization for surgery during pregnancy. Our study is larger, and more recent, perhaps reflecting improvements in surgery, but (like Duncan's) is unable to disassociate the risk of surgery from the risk of anesthesia or the underlying condition for which the procedure was carried out. Unlike Duncan's, our data include all surgical patients, and the dataset did not allow us to determine whether they had a general anesthetic, although it is likely that the majority did so. For abdominal surgery, we found an even higher risk of miscarriage (associated with a hospital admission) with a RR = 1.90 (95% CI 1.81–1.99), and of preterm delivery RR = 1.62 (95% CI 1.54–1.70) than women who had no surgery. In contrast, Gerstenfield et al[31] found no significant difference in preterm delivery rate when comparing women who had abdominal surgery to women who did not have surgery (OR 1.13, 95% CI 0.56–2.25, $P = 0.84$), and only 2 cases of spontaneous abortion following surgery. Their study was small, and included only 106 women who underwent surgery. However, in our study, we are likely missing a large number of pregnancies ending in miscarriage, as many are never hospitalized. We found a significant difference between laparoscopic and open abdominal surgery for risk of miscarriage (RR 3.82, 95% CI 3.29–4.41). There may be a reluctance by surgeons to perform laparoscopic surgery beyond 26 to 28-week gestation because of perceived or real practical difficulties and previous evidence,[32] and although this has more recently been refuted[33] may still reflect common practice. As we are unable to determine gestational age for miscarriage, the estimated risk for laparoscopic surgery may be biased, given the timing of procedures, relative with open procedures.

In our study, we identified 235 maternal fatalities, which corresponded to a maternal death rate of 4 per 100,000. Our estimate is much lower than national estimates (10 per 100,000, report ''Saving Lives, Improving Mothers' Care,'' December 9, 2014) because we only identified maternal deaths occurring in the same admission as the delivery or miscarriage. We were not able to capture maternal deaths wherein no delivery occurred (deaths wherein mother died before delivery), or deaths outside hospital. In relation to nonobstetric surgery during pregnancy, we estimated a RR of 4.72 (95% CI 2.61–8.52). The baseline risk of maternal death is fortunately very low, and translates into NNHs of 7692 procedures associated with 1 additional maternal death. This was based on only

TABLE 4. Adjusted Relative Risks (RRs), Attributable Risks (ARs), and Number Needed to Harm (NNH) of Adverse Birth Outcomes Associated With all Nonobstetric Surgery During Pregnancy

Outcome	Overall Crude Rate (%)	RR*	RR†	AR (%)†	NNH†	Number of Outcomes per 100 Operations
Miscarriage associated with hospitalization	5.8	1.13 (1.09–1.17)	1.12 (1.08–1.16)	0.7 (0.4–0.9)	143 (107–230)	0.7
Stillbirth	0.6	1.64 (1.50–1.81)	1.64 (1.47–1.80)	0.4 (0.3–0.4)	287 (227–386)	0.3
Preterm delivery	7.5	1.43 (1.39–1.47)	1.42 (1.39–1.46)	3.2 (2.9–3.4)	31 (29–34)	3.2
Low birth weight	5.6	1.49 (1.44–1.54)	1.46 (1.43–1.53)	2.6 (2.5–2.9)	39 (37–42)	2.6
Cesarean section	23.9	1.21 (1.19–1.23)	1.17 (1.15–1.19)	4.0 (3.6–4.5)	25 (22–28)	4
Long inpatient stay	9.5	1.22 (1.20–1.25)	1.21 (1.18–1.26)	2.0 (1.7–2.4)	50 (41–60)	2
Maternal death	0.004	4.72 (2.61–8.52)	4.67 (1.79–8.93)	0.013 (0.003–0.028)	7692 (3571–33333)	0.01

*Relative risk estimated directly from logistic regression.
†Relative risk, attributable risk, and number needed to harm estimated using Austin method.

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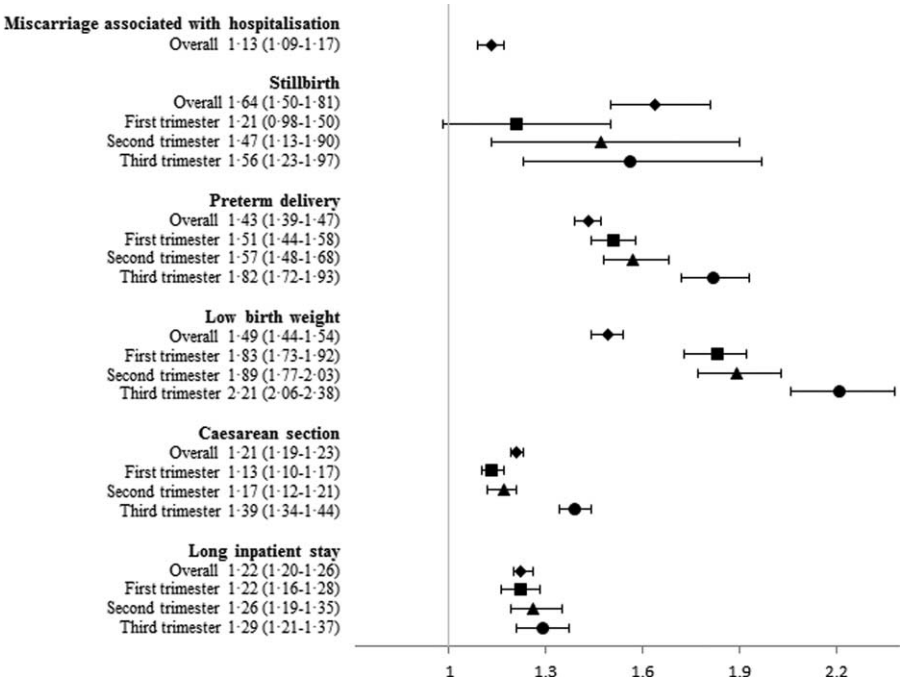


FIGURE 1. Forest plot of relative risks (RRs) of adverse birth outcomes, overall and by trimester. Adjusted overall RRs and 95% CI were estimated using all sample (n = 6,486,280) and adjusted RRs and 95% CI by trimester were estimated using observations were gestational age was known (n = 3,935,825).

12 women who died in our cohort during or after surgery during pregnancy, and so the CIs are wide. There is only 1 previous study reporting the maternal death of a woman undergoing laparoscopic cholecystectomy and a maternal death of 0.006% was estimated.[34] Contrary to our study, the latter study was very small and presented only crude risk.

Our study revealed that in pregnancies wherein nonobstetric surgery occurred has an increased risk of stillbirth and low birth weight compared with those pregnancies wherein surgery did not occur. We found that pregnant women who underwent nonobstetric surgery had an AR of 0.4% for stillbirth and 2.6% for low birth weight compared with women who did not have surgery. However, there were no significant differences in the risk of low birth weight and stillbirth in women undergoing laparoscopic versus open abdominal surgery. Contrary to our findings, a Swedish study[4] concluded that the incidence of stillbirth was not increased in women having an operation. However, the incidence of very low and low birth weight infants was increased. Mazze and Kallen[35] investigated appendicectomy and laparoscopic surgery, and did not observe a statistically significant increase in stillbirth. But the authors concluded that the mean birth weight in the operated group was on average 78 g less than the expected birth weight. In both studies, analysis was conducted on the data collected between 1973 and 1981, which is now over 30 years old and is therefore unlikely to be representative of current situation.

Interestingly, the point estimates demonstrated in Fig. 1 (except for miscarriage) seem to show an increasing risk with successive trimesters. However, this may reflect that the severity of the condition necessitating surgical intervention is greater, given the natural reluctance to intervene in women at an advanced stage of pregnancy.

There are a number of limitations that need to be considered when interpreting the findings. The first is around data quality and completeness. Submission of HES records is mandatory and in general coverage is very high. Most debate around HES data quality concerns the primary and secondary diagnostic and procedure field.[36–39] Nonetheless, a recent systematic review of discharge coding accuracy in routine UK data found that primary diagnosis accuracy has improved from 73.8% to 96.0% in the 10 years since the introduction of Payment by Results.[40] Not all delivery records contain supplementary information, although the percentage of records with a complete maternity tail has improved over time.[41] HES data have more general limitations in the recording other potential confounders. It is well known that body mass index (BMI), smoking status, and environmental factors such as air pollution are important risk factors for adverse outcomes in pregnancy; however, these variables are not recorded.

A further limitation to our study is that we treat surgery during pregnancy as a homogenous intervention, and are unable to disentangle the independent effects of anesthesia, the various indications for surgery, as well as the surgery itself, all of which may influence the outcome of pregnancy. Thus, we are not able to estimate the independent contribution to the risks of an adverse outcome during pregnancy of each component of this complex intervention.

A specific limitation is around miscarriage associated with hospitalization. Our definition of miscarriage associated with hospitalization represents only a proportion of all miscarriages. It may be more likely to be reported if it occurs in same hospital admission as a procedure, and this could account for the associated increased risk with surgery during pregnancy. However, only 1.8% of miscarriage associated with hospitalization actually occurred in same admission as the procedure. Because of the potential for ascertainment bias, temporal issues around recording of risk factors, and other unaccounted for confounding related to gestational age, we urge caution when interpreting the risk of miscarriage associated with nonobstetric surgery during pregnancy.

A strength of this study is the size of the database, allowing for adjustment of multiple obvious confounders, so some estimates of risk can be dependably derived. This type of clinical area does not lend itself to clinical trials and is too complex for plausible propensity matching as an alternative.

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TABLE 5. Adjusted Relative Risks (RRs), Attributable Risks (ARs), and Number Needed to Harm (NNH) for Common Procedure Group

Outcome	RR (95% CIs)*	RR†	AR (%)†	NNH*,†
Abdominal vs no surgery				
Miscarriage associated with hospitalization	1.90 (1.81–1.99)	1.87	5.0	20
Stillbirth	1.76 (1.47–2.11)	1.76	0.4	240
Preterm delivery	1.62 (1.54–1.70)	1.51	3.6	28
Low birth weight	1.61 (1.51–1.71)	1.57	3.2	32
Cesarean section	1.27 (1.23–1.30)	1.21	5.0	20
Long inpatient stays	1.30 (1.24–1.37)	1.29	2.8	36
Abdominal laparoscopic vs no surgery				
Miscarriage associated with hospitalization	2.47 (2.34–2.60)	2.41	8.2	12
Stillbirth	1.72 (1.37–2.16)	1.72	0.3	253
Preterm delivery	1.52 (1.43–1.62)	1.50	3.7	27
Low birth weight	1.54 (1.43–1.66)	1.51	2.8	35
Cesarean section	1.21 (1.16–1.26)	1.17	4.0	25
Long inpatient stay	1.29 (1.21–1.37)	1.28	2.7	37
Abdominal open vs no surgery				
Miscarriage associated with hospitalization	0.65 (0.56–0.76)	0.66	−1.9	N/A
Stillbirth	1.84 (1.36–2.50)	1.84	0.4	217
Preterm delivery	1.80 (1.67–1.96)	1.77	5.8	17
Low birth weight	1.72 (1.57–1.89)	1.67	3.8	26
Cesarean section	1.37 (1.30–1.44)	1.29	7.0	14
Long inpatient stay	1.32 (1.22–1.43)	1.31	2.9	34
Appendicectomy vs no surgery				
Miscarriage associated with hospitalization	0.78 (0.66–0.92)	0.79	−1.2	N/A
Stillbirth	1.05 (0.65–1.68)	—	—	—
Preterm delivery	1.49 (1.34–1.64)	1.46	3.5	28
Low birth weight	1.43 (1.26–1.62)	1.40	2.2	44
Cesarean section	1.13 (1.06–1.21)	1.11	2.6	39
Long inpatient stay	1.32 (1.20–1.46)	1.32	3.0	33
Dental vs no surgery				
Miscarriage associated with hospitalization	1.01 (0.91–1.12)	—	—	—
Stillbirth	1.62 (1.23–2.16)	1.62	0.3	292
Preterm delivery	1.13 (1.04–1.24)	1.12	1.1	91
Low birth weight	1.32 (1.20–1.46)	1.30	1.7	59
Cesarean section	0.97 (0.92–1.02)	—	—	—
Long inpatient stay	1.12 (1.04–1.21)	1.12	1.3	77
Perianal vs no surgery				
Miscarriage associated with hospitalization	0.58 (0.46–0.67)	0.59	−2.5	N/A
Stillbirth	0.59 (0.32–1.11)	—	—	—
Preterm delivery	0.86 (0.75–0.99)	0.89	-0.8	N/A
Low birth weight	0.93 (0.80–1.08)	—	—	—
Cesarean section	1.17 (1.10–1.25)	1.18	3.9	25
Long inpatient stay	1.08 (0.97–1.20)	—	—	—
Orthopedic vs no surgery				
Miscarriage associated with hospitalization	0.94 (0.84–1.07)	—	—	—
Stillbirth	1.38 (0.99–1.93)	—	—	—
Preterm delivery	1.18 (1.08–1.30)	1.18	1.3	75
Low birth weight	1.34 (1.21–1.49)	1.32	1.8	56
Cesarean section	1.11 (1.05–1.17)	1.09	2.1	47
Long inpatient stay	1.19 (1.09–1.29)	1.18	1.7	57
ENT vs no surgery				
Miscarriage associated with hospitalization	1.07 (0.93–1.23)	—	—	—
Stillbirth	1.52 (1.04–2.21)	1.51	0.3	356
Preterm delivery	1.22 (1.09–1.36)	1.22	1.6	63
Low birth weight	1.39 (1.22–1.57)	1.36	2.0	49
Cesarean section	1.01 (0.94–1.07)	—	—	—
Long inpatient stay	1.15 (1.05–1.27)	1.15	1.4	71
Breast vs no surgery				
Miscarriage associated with hospitalization	0.74 (0.60–0.91)	0.74	−1.5	N/A
Stillbirth	1.19 (0.67–2.08)	—	—	—
Preterm delivery	1.94 (1.74–2.17)	1.90	6.7	15
Low birth weight	1.94 (1.70–2.21)	1.87	4.9	20
Cesarean section	1.17 (1.08–1.27)	1.14	3.4	30
Long inpatient stay	1.13 (0.98–1.27)	—	—	—

N/A indicates not available.
*Relative risk estimated directly from logistic regression.
†Relative risk, attributable risk, and number needed to harm estimated using Austin method.

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Our study is much more recent than other studies and reflects current risks in light of improvements to anesthesia and surgical procedures. General principles regarding the care of pregnant women requiring nonobstetric surgery have not changed significantly in the past 20 years. The anesthetic drugs used however have changed over time and there has been an increased use of laparoscopic surgery, as surgical experience has demonstrated that this is safe in pregnancy.[42,43]

CONCLUSIONS

As far as we are aware, this is the most recent study to report the risk of adverse birth outcomes following nonobstetric surgery during pregnancy. We found that the overall AR of an adverse birth outcome in women having surgery during their pregnancy compared with women who did not was generally low. A key limitation is that we are unable to separate the risk of the underlying condition (for which surgery was carried out) from the surgery itself, and the limitations of our data for defining miscarriages and maternal deaths in hospital mean that these indicators do not adequately reflect the whole risk for these outcomes. However, we still believe that in particular, the NNHs for the other indicators will be helpful to women and their surgeons to make better individual decisions based on better information. Clearly, surgery during pregnancy should only be considered if absolutely necessary; however, we believe that for those whose optimal treatment includes surgery, our analysis may provide some reassurance to mothers concerning the risks to their pregnancy.

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