OBSTETRICS

Risk of spontaneous preterm birth elevated after first cesarean delivery at full dilatation: a retrospective cohort study of over 30,000 women

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BACKGROUND: Having a cesarean delivery at full dilatation has been associated with increased subsequent risk of spontaneous preterm birth. The Aberdeen Maternity and Neonatal Databank provides a rare opportunity to study subsequent pregnancy outcomes after a previous cesarean delivery at full dilatation over 40 years, with an ability to include a detailed evaluation of potential confounding factors.

OBJECTIVE: This study aimed to investigate if having an initial cesarean delivery at full dilatation is associated with spontaneous preterm birth or other adverse pregnancy outcomes in the subsequent pregnancy.

STUDY DESIGN: A retrospective cohort study was conducted including women with a first and second pregnancy recorded within the Aberdeen Maternity and Neonatal Databank between 1976 and 2017, where previous cesarean delivery at full dilatation at term in the first birth was the exposure. The primary outcome was spontaneous preterm birth (defined as spontaneous birth <37 weeks). Multivariate logistic regression was used to investigate any association between cesarean delivery at full dilatation and the odds of spontaneous preterm birth. Cesarean delivery at full dilatation in previous pregnancy was compared with: (1) any other mode of birth, and (2) individual modes of birth, including planned cesarean delivery, cesarean delivery in first stage of labor (<10-cm dilatation), and vaginal birth (including spontaneous vaginal birth, nonrotational forceps, Kielland forceps, vacuum-assisted birth, breech vaginal birth). Other outcomes such as antepartum hemorrhage and mode of second birth were also compared.

RESULTS: Of the 30,253 women included, 900 had a previous cesarean delivery at full dilatation in the first pregnancy. Women with previous cesarean delivery at full dilatation had a 3-fold increased risk of spontaneous preterm birth in a second pregnancy (unadjusted odds ratio,

2.63; 95% confidence interval, 1.82—3.81; adjusted odds ratio, 3.31; 95% confidence interval, 2.17—5.05) compared with those with all other modes of first birth, adjusted for maternal age, diabetes mellitus, body mass index, smoking, preeclampsia, antepartum hemorrhage, socioeconomic deprivation (Scottish Index of Multiple Deprivation 2016), year of birth, and interpregnancy interval (in second pregnancy). When compared with women with vaginal births only, women with cesarean delivery at full dilatation had 5-fold increased odds of spontaneous preterm birth (adjusted odds ratio, 5.37; 95% confidence interval, 3.40—8.48). Compared with first spontaneous vaginal birth, first instrumental births (nonrotational forceps, Kielland forceps, and vacuum births) were not associated with increased risk of spontaneous preterm birth in the second birth. After an initial cesarean delivery at full dilatation, 3.7% of women had a repeated cesarean delivery at full dilatation and 48% had a planned cesarean delivery in the second birth.

CONCLUSION: This study is a substantial addition to the body of evidence on the risk of subsequent spontaneous preterm birth after cesarean delivery at full dilatation, and demonstrates a strong association between cesarean delivery at full dilatation in the first birth and spontaneous preterm birth in subsequent pregnancy, although the absolute risk remains small. This is a large retrospective cohort and includes a comprehensive assessment of potential confounding factors, including preeclampsia, antepartum hemorrhage, and lengths of first and second stage of labor. Future research should focus on understanding possible causality and developing primary and secondary preventative measures.

Key words: caesarean section, full dilatation caesarean, second stage caesarean, spontaneous preterm birth

Introduction

Preterm birth (PTB) and its associated complications remain the leading cause of neonatal mortality globally.[1] Estab-

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lishing causes of PTB and effective preventative management is a global health need. PTB is defined as a birth before 37 weeks of gestation.[2] It is estimated that 15 million PTBs occur per year worldwide,[3] with approximately 6% of infants born preterm each year in Scotland and the United Kingdom, and 1 in 10 infants born preterm in the United States.[4—6] Outcomes worsen with increasing prematurity.[4] Spontaneous PTB (sPTB) is considered to account for 75% of PTBs,[4] with the remainder being iatrogenic, where maternal or fetal concerns lead to intervention to expedite birth.

Research has suggested that there may be increased risk of PTB in pregnancies

following a cesarean delivery (CD) performed in the second stage of labor (when the cervix is fully [ie, 10 cm] dilated) (CDfd).[7—12] However, some of the previously published cohorts were small, single-center, and with risk of selection bias given that subsequent pregnancies may not have been collected in the same data sets. It is hypothesized that injury to the cervix at the time of CD—specifically by inadvertently incising through the cervix at the time of CD surgery—could increase the risk of subsequent sPTB,[13,14] but we ultimately do not know why such an association may exist. Evidence is varied, with one study suggesting that there was no risk of

AJOG at a Glance

Why was this study conducted?
This retrospective cohort study aimed to investigate the impact of having a cesarean delivery (CD) at full dilatation in first term pregnancy on outcomes in the next pregnancy, including spontaneous preterm birth.

Key findings
Spontaneous preterm birth is strongly associated with a history of CD at full dilatation compared with all other modes of birth, and odds may be increased as much as 5-fold compared with first term vaginal birth.

What does this add to what is known?
This large retrospective cohort study contributes to the growing evidence of the increased risk of spontaneous preterm birth after CD at full dilatation, with a detailed assessment of potential confounding factors. This study includes comparisons of CD at full dilatation with all other modes of birth, and comparisons with individual modes of birth including rotational and nonrotational deliveries and breech vaginal births.

spontaneous or iatrogenic PTB after term CD.[15] However, Levine et al[8] found that women had 5 times greater odds of sPTB after CDfd compared with women who had first-stage CD, suggesting that the risk may be specifically associated with CDfd. Similarly, Cong et al[9] found that women with CDfd were twice as likely to have sPTB compared with women with a first-stage CD.

Rates of CD appear to be increasing.[5,13,16—19] From 2020 to 2021, the percentage of infants in Scotland born by CD rose to 36%, amounting to 1 in 3 live-born singleton infants in Scotland.[5] In the United States, over 30% of infants in 2020 were born by CD.[20] The incidence of CDfd also appears to be increasing.[13,16—18] Studies have reported varying rates of CDfd from 5%[17] to 20%,[9] although this may vary globally, particularly in countries where assisted vaginal birth is not practiced. It is essential that any adverse sequelae of having a CDfd are recognized, and preventative measures developed. This study aimed to investigate if having a CDfd in the first term birth is associated with increased risk of sPTB in subsequent pregnancy when compared with all other modes of birth. It was hypothesized that other adverse pregnancy outcomes, such as premature prelabor rupture of membranes (PPROM) or antepartum hemorrhage (APH), may increase if the cervix is weakened or the CDfd scar affects future placentation. The Aberdeen Maternity and Neonatal Databank (AMND) provides a rare opportunity to investigate the prevalence of CDfd over 40 years and subsequent reproductive outcomes for women in a geographic area with a low outmigration rate.[21]

Materials and Methods
A retrospective cohort study was conducted to compare subsequent birth outcomes between women with and without a history of CDfd in the first term birth. The population included all women who had a term live birth (defined as an infant born at ≥37 weeks of gestation) in their first pregnancy and who had a second birth from 24 weeks of gestation recorded within the AMND. First pregnancies resulting in a term birth (infants born from 37—44 weeks of gestation) by any mode of birth from 1976 until 2016, and second pregnancies with singleton live births from 24 weeks of gestation from 1977 to 2017 were included. The exposed cohort was defined as all women who had a CDfd in their first pregnancy. The unexposed cohort included all women who did not have a CDfd in their first pregnancy (including all vaginal births [spontaneous or assisted], elective CD [women not in labor at time of CD], and women who had a CD in the first stage of labor [at <10-cm dilatation]). The binary primary outcome was defined as sPTB in the second pregnancy, where labor commenced spontaneously, and a birth occurred from 24+0 to 36+6 weeks of gestation. We also investigated all PTBs and stratified according to gestation: >36 weeks, preterm (34—36 weeks), and very preterm (<34 weeks). Secondary outcomes included APH, mode of birth in the second pregnancy, labor type in the second pregnancy (induced or spontaneous), PPROM, blood loss at second birth, interpregnancy interval, threatened miscarriage, birthweight, and neonatal unit (NNU) admission. Women with multiple pregnancies in their first or second births; any preterm delivery in the first pregnancy (<37 weeks' gestation); first pregnancy ending in miscarriage, ectopic pregnancy, termination of pregnancy, or molar pregnancy; or second births ending in miscarriage, ectopic pregnancy, molar pregnancy, or termination of pregnancy were excluded.

Second pregnancy outcomes were compared between the exposed (women with CDfd in first birth) and unexposed group (all other modes of first birth). Subgroup analyses were performed comparing women with previous CDfd with those with all other previous modes of birth individually, including spontaneous vaginal birth (SVB), instrumental vaginal birth (including nonrotational forceps, Kielland rotational forceps, vacuum and breech vaginal birth), elective CD, and first-stage CD (CD before full dilatation in the first stage of labor where the cervix was dilated ≤9 cm). First-stage CD was identified within the AMND data by selecting women with a recorded first stage of labor, confirming that they had been in labor but with no second stage documented, and that CD was performed before 10-cm dilatation. CDfd was defined by identifying women with a CD where the first and second stage of labor were recorded but the eventual mode of birth was CD.

This study is reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidance.[22] Approval was

obtained from the AMND Steering Committee (reference: AMND2020-01) to undertake this study. The AMND Steering Committee has overarching ethical approval for studies that use pseudoanonymized data with no data linkage, and therefore formal ethics approval was not required. The AMND holds routinely collected pregnancy data for all women who gave birth in Aberdeen Maternity Hospital from 1949 until the present day.[21] All pregnancy records were included automatically in the AMND until 2017,[21] and the information was entered routinely for all women under the jurisdiction of Aberdeen Maternity Hospital until 2017, which is the only maternity hospital in the area. Before 1976, CDfd was not recorded within the AMND, and therefore women were included only after this date. A pseudoanonymized data set was provided to the researchers and was analyzed within the Grampian Data Safe Haven in accordance with data protection laws. No data linkage was performed, and no raw data were transferred out of the safe haven. Data can be made available by applying to the AMND for permission (amnd@abdn.ac.uk).

Definitions of outcomes

Gestation at birth is coded according to the due date that was estimated by the first-trimester ultrasound scan when available from hospital records (from 1986 onward), and otherwise by the last menstrual period date that was recorded at first antenatal booking and the date of birth. APH was defined in the AMND as vaginal bleeding after 24 weeks' gestation, which includes abruption and placenta previa, and a binary variable for APH (yes/no) was computed for this study. Interpregnancy interval was automatically calculated from the recorded year of birth from the first to the second pregnancy.

Definition of confounders

Deprivation was recorded using the Scottish Index of Multiple Deprivation (SIMD 2016),[23] with 1 indicating lowest deprivation and 10 highest deprivation, and this was recorded routinely in the AMND. SIMD[23] is a marker of

socioeconomic status for zip code geographic areas in Scotland, and an objective measure of how deprived an area is, and uses information from 6 categories including income, employment, education, access to health services, crime, and housing. Maternal age at infant's birth was collected routinely by the AMND from the hospital medical records. Smoking status was self-reported at the time of antenatal booking and documented within the hospital record from which it was collected for inclusion within the AMND. Preeclampsia is defined as gestational hypertension and at least 1 episode of proteinuria (>0.3 g of protein in 24 hours); this information was directly collected from the hospital records. Any history of diabetes mellitus was included to compute a binary variable for diabetes (yes/no).

Statistical analysis

All data were stored and analyzed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY). Parametric and nonparametric tests were used to compare normally and nonnormally distributed variables, respectively. One-way ANOVA (analysis of variance) test was used to compare means for normally distributed variables (age, birthweight) across 4 modes of birth. The chi-square test was used to compare categorical variables. Binary logistic regression models were used to identify any associations between the exposure (history of CDfd in the first pregnancy) and the primary (sPTB) and secondary outcomes (APH, preeclampsia, threatened miscarriage, and NNU admission). Multinomial logistic regression was used to identify any association between the exposure (history of CDfd in the first pregnancy) and categorical outcomes ([1] different modes of birth with SVB as the reference category; [2] any PTB with full-term birth as the reference category). Multivariable models were used to adjust for potential confounding factors. The potential confounders were different between outcomes and are reported in footnotes under the tables. The strength of measure of association was estimated using odds ratios (ORs),

adjusted ORs (aORs), and 95% confidence intervals (CIs). P values of $<.05$ were deemed statistically significant.

Potential confounding factors were included from the first pregnancy (APH, preeclampsia, socioeconomic status, any history of diabetes mellitus, birthweight, and length of first and second stage of labor [where applicable]) and from the second pregnancy (maternal age at second birth, body mass index [BMI], smoking, preeclampsia, APH, year of birth, and interpregnancy interval). Although the evidence is varied,[24–27] prolonged duration of the second stage of labor has been associated with increased risk of sPTB[28] and is inherently associated with likelihood of having a CDfd. Therefore, lengths of the first and second stage of labor were included in a multivariate model where appropriate (CDfd vs all types of vaginal birth); aORs are shown with and without inclusion of length of first and second stage of labor.

Complete-case analyses were conducted. Where the proportion of missing data was $>5\%$ for covariates, a sensitivity analysis was conducted for adjusted analyses excluding smoking, BMI, socioeconomic status, and length of first and second stage of labor from the multivariate analyses. Multiple imputation was also used to impute values for smoking, BMI, and deprivation where missing values exceeded 5%, and separate multivariate analyses were performed with imputed values using the automatic method within IBM SPSS Statistics software ("the Automatic method scans the data and uses the monotone method if the data show a monotone pattern of missing values; otherwise, fully conditional specification is used. The fully conditional specification [FCS] imputation method imputes values in the order specified in the Analysis Variables list").[29]
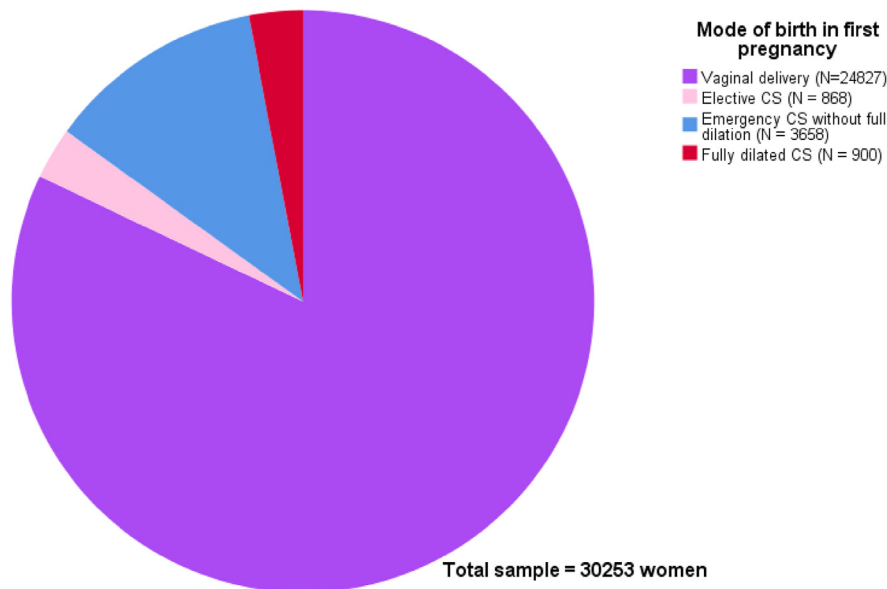
Results

A total of 30,253 primigravid women who had a first and second pregnancy recorded within the AMND were included.

First pregnancies

Figure 1 shows the proportion of each mode of birth in the first pregnancy. Of the women deemed eligible for inclusion,

FIGURE 1
Mode of birth in first pregnancy (1976–2016; N = 30,253)

CS, cesarean section.

Woolner. Subsequent spontaneous preterm birth risk is increased after first cesarean delivery at full dilatation. Am J Obstet Gynecol 2024.

24,827 had a vaginal birth in their first pregnancy, 868 had an elective (planned) CD, 3658 had a CD in the first stage of labor, and 900 women had a CDfd. Figure 2 demonstrates the number of women within this study population for each mode of birth in the first pregnancy over time. The number of primigravid women having a CDfd appears stable over time within this study population. Demographic and pregnancy characteristics for the first pregnancy are shown in Table 1. Women who had a CDfd were significantly more likely to have infants

FIGURE 2
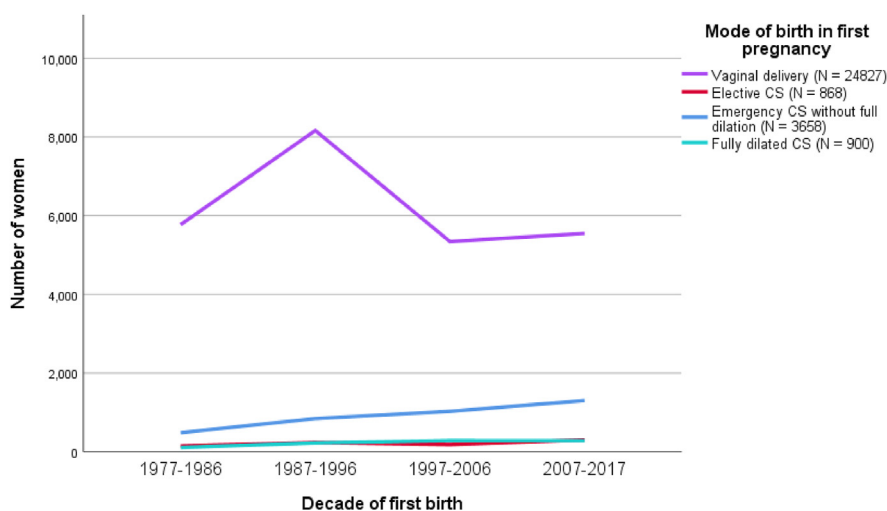**Line graph of mode of birth in first pregnancies over time (N = 30,253)**

CS, cesarean section.

Woolner. Subsequent spontaneous preterm birth risk is increased after first cesarean delivery at full dilatation. Am J Obstet Gynecol 2024.

with a greater birthweight and admission to the NNU compared with women with all other birth modes, and most strikingly when compared with women with vaginal birth.

Second pregnancies
Spontaneous preterm birth

Table 2 shows the demographic and pregnancy characteristics in the second pregnancy according to the mode of birth in the first pregnancy. Women with an initial CDfd were significantly more likely to have a sPTB in the subsequent pregnancy compared with women with no history of CDfd. Specifically, 1.6% (n=32) more women in the exposed group had a subsequent sPTB compared with women who had an initial elective or first-stage CD, and 1.3% more compared with women who had a vaginal birth. When all PTBs (spontaneous and iatrogenic) were considered, 5.3% of women with a previous CDfd had a PTB in the second pregnancy. Table 3 demonstrates the results of the comparative analyses for women in the exposed group (women with a previous CDfd) vs all other births, and subgroup comparisons with each individual mode of initial birth for the outcome of PTB and sPTB, with PTB defined as live births from 24+0 to 36+6 weeks. Women with initial CDfd were found to have 3-fold increased odds of having a subsequent sPTB compared with women with any other previous mode of birth (aOR, 3.31; 2.17–5.05). When values were imputed where the proportion of missing data for covariates was >5% (smoking, deprivation, BMI), the association was confirmed as 3-fold higher for women with a CDfd in their first pregnancy (aOR, 3.06; 95% CI, 2.61–3.59) compared with those with all other births, and similarly when sensitivity analysis was conducted (Supplemental Table).

Compared with women with a first vaginal birth only, there remained 3-fold increased odds of sPTB in women with a first CDfd (aOR, 3.70; 95% CI, 2.42–5.67), which increased to 5-fold when lengths of first and second stage were included in the multivariate analyses as potential confounders (aOR, 5.37; 95% CI, 3.40–8.48) (Table 3). Compared with women with a CD in the

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TABLE 1
First pregnancy demographic, obstetrical, and perinatal characteristics (1976−2016); N=30,253

First pregnancy variable	Mode of birth in first pregnancy				P value
	Vaginal birth N=24,827 n (%)	Elective CD N=868 n (%)	First-stage CD N=3658 n (%)	Second-stage CD N=900 n (%)	
Age (y)					<.01[a]
16−25	13,386 (53.9)	304 (35.0)	1418 (38.8)	364 (40.4)	
26−35	11,068 (44.6)	522 (60.1)	2092 (57.2)	511 (56.8)	
>35	373 (1.5)	42 (4.8)	148 (4.0)	25 (2.8)	
Smoking					<.01[a]
Nonsmoker	12,689 (51.1)	523 (60.3)	2281 (62.4)	590 (65.6)	
Smoker	6135 (24.7)	159 (18.3)	677 (18.5)	125 (13.9)	
Former smoker	1346 (5.4)	46 (5.3)	250 (28.8)	70 (7.8)	
Missing	4657 (18.8)	140 (16.1)	450 (12.3)	115 (12.8)	
Body mass index					<.01[a]
<20	2280 (9.2)	66 (7.6)	190 (5.2)	46 (5.1)	
20−25	11,944 (48.1)	375 (43.2)	1511 (41.3)	377 (41.9)	
25−30	5083 (20.5)	215 (24.8)	974 (26.6)	253 (28.1)	
>30	1855 (7.5)	93 (10.7)	608 (16.6)	129 (14.3)	
Missing	3665 (14.8)	119 (13.7)	375 (10.3)	95 (10.6)	
Deprivation (SIMD 2016)					<.01[a]
1−5 (least deprived)	7099 (28.6)	217 (25.0)	951 (26.0)	212 (23.6)	
6−10 (most deprived)	16,583 (66.8)	587 (67.7)	2458 (67.2)	619 (68.8)	
Missing	1145 (4.6)	64 (3.7)	249 (6.8)	69 (7.7)	
Diabetes mellitus (any)					<.01[a]
Yes	229 (0.9)	37 (4.3)	94 (2.6)	20 (2.2)	
No	24,598 (99.1)	831 (95.7)	3564 (97.4)	880 (97.8)	
Antepartum hemorrhage					<.01[a]
Yes	2202 (8.9)	99 (11.4)	391 (10.7)	74 (8.2)	
No	22,625 (91.1)	796 (91.7)	3267 (89.3)	826 (91.8)	
Preeclampsia					<.01[a]
Yes	7042 (28.4)	224 (25.8)	1300 (35.6)	321 (35.7)	
No	17,785 (71.6)	644 (74.2)	2358 (64.5)	579 (64.3)	
Threatened miscarriage					.01[a]
Yes	4215 (17.0)	180 (20.7)	582 (15.9)	140 (15.6)	
No	20,612 (83.0)	688 (79.3)	3076 (84.1)	760 (84.4)	
Labor type					<.01[a]
Spontaneous	17,268 (69.6)	n/a	1755 (48.0)	558 (62.0)	
Induced	7557 (30.4)	n/a	1903 (52.0)	342 (38.0)	
Missing	2		0	0	
Length of first stage labor (h)					<.01[a]
Median	8.0	n/a	n/a	12	
Missing	5058			149	

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TABLE 1
First pregnancy demographic, obstetrical, and perinatal characteristics (1976–2016); N = 30,253 (continued)

First pregnancy variable	Mode of birth in first pregnancy				P value
	Vaginal birth N=24,827 n (%)	Elective CD N=868 n (%)	First-stage CD N=3658 n (%)	Second-stage CD N=900 n (%)	
Length of second stage labor (h)					<.01[a]
Median	1.0	n/a	n/a	1.0	
Missing	1662 (6.7)			103 (11.4)	
Neonatal unit admission					<.01[a]
Yes	1417 (5.7)	98 (11.3)	468 (12.8)	140 (15.6)	
No	23,410 (94.3)	770 (88.7)	3190 (87.2)	760 (84.4)	
Blood loss					<.01[a]
Median (IQR)	200 (150)	450 (300)	500 (325)	500 (400)	
Missing	71	15	28	4	
Presentation/position of fetal head					<.01[a]
OA	21,895 (88.2)	287[b] (33.1)	2287 (62.5)	330 (36.7)	
OP	1384 (5.6)	—	581 (15.9)	268 (29.8)	
OT	1233 (4.9)	—	315 (8.6)	200 (22.2)	
Breech	205 (0.8)	572 (65.9)	392 (10.7)	84 (9.3)	
Other	93 (0.4)	7 (0.8)	70 (1.9)	17 (1.9)	
Missing	17 (0.1)	2 (0.2)	13 (0.4)	1 (0.1)	
Gestation at birth (wk)					
Median	40	39	40	40	<.01[a]
Birthweight (g)					<0.01[a]
Mean (SD)	3350 (590)	3280 (678)	3540 (700)	3600 (620)	
Missing	0	0	1	0	

CD, cesarean delivery; *IQR*, interquartile range; *OA*, occiput anterior; *OP*, occiput posterior; *OT*, occiput transverse; *SIMD*, Scottish Index of Multiple Deprivation.

[a] Statistically significant; [b] Includes OP and OT because of small counts.

Woolner. Subsequent spontaneous preterm birth risk is increased after first cesarean delivery at full dilatation. Am J Obstet Gynecol 2024.

first stage of labor, women with a CDfd had higher odds of sPTB (aOR, 1.83; 95% CI, 1.12–2.99). Women with an initial elective CD did not have higher odds of sPTB when compared with women with first vaginal births. Having a first-stage CD in the initial birth was associated with increased odds of sPTB in the subsequent pregnancy (aOR, 1.82; 95% CI, 1.36–2.44). Compared with women with first vaginal births, women with first births via first- or second-stage CD had a 2-fold increase in the risk of sPTB (aOR, 2.18; 95% CI, 1.70–2.81). A significant proportion of women (48.3%) with an initial CDfd had an elective CD for their second birth. Women with a previous CDfd had 20-fold increased odds of having a

subsequent CDfd (aOR, 20.2; 95% CI, 12.9–31.7), and 50-fold increased odds of having an elective CD (aOR, 51.5; 95% CI, 42.3–62.8) in the second birth.

Table 4 demonstrates the univariate and multivariate analyses using multinomial logistic regression models to compare subsequent pregnancy outcomes (sPTB and any PTB) between all types of vaginal birth (including spontaneous, assisted vaginal, and breech vaginal births) and CDfd in the first pregnancy. CDfd remained significantly associated with subsequent risk of sPTB (aOR, 5.17; 95% CI, 3.15–8.48). Breech vaginal birth was associated with increased odds of sPTB and PTB, with 6.7% of those with a breech vaginal birth having a sPTB in the next pregnancy, as

opposed to 3.3% of women who had SVB. However, the association with sPTB was not statistically significant in the multivariate analysis (aOR, 1.97; 95% CI, 0.95–4.10). All other types of first vaginal births, including nonrotational forceps, rotational forceps (Kielland), and vacuum were not associated with subsequent risk of sPTB compared with women with first SVB, and many of the unadjusted ORs notably suggest a protective effect, although none of the results were statistically significant.

Comment
Principal findings
Previous CDfd is associated with greater risk of sPTB in subsequent pregnancy compared with all other modes of first

TABLE 2
Second pregnancy demographic, obstetrical, and perinatal characteristics according to mode of birth in first pregnancy; N=30,253

Second pregnancy outcome N=30,253	Mode of birth in first pregnancy, n (%)				P value
	Vaginal birth N=24,827 n (%)	Elective CD N=868 n (%)	First-stage CD N=3658 n (%)	Second-stage CD N=900 n (%)	
Any preterm birth (24—36 wk)	881 (3.5)	38 (4.4)	125 (3.4)	48 (5.3)	.02[a]
Term birth (37—44 wk)	23,946 (96.5)	830 (95.6)	3533 (96.6)	852 (94.7)	
Preterm birth (34—36 wk)	658 (2.7)	31 (3.6)	99 (2.7)	38 (4.2)	.02[a]
Preterm birth (<34 wk)	223 (0.9)	7 (0.8)	26 (0.7)	10 (1.1)	.59
Spontaneous preterm birth (24—36 wk)	568 (2.3)	17 (2.0)	72 (2.0)	32 (3.6)	<.01[a]
Age at delivery (y)					<.01[a]
16—25	7714 (31.1)	153 (17.6)	710 (19.4)	183 (20.3)	
26—35	15,455 (62.2)	578 (66.6)	2440 (66.7)	615 (68.3)	
>35	1658 (6.7)	137 (15.7)	508 (13.9)	102 (11.3)	
Smoking (N=26,131)					<.01[a]
Smoker	5424 (21.8)	136 (15.7)	604 (18.1)	117 (14.3)	
Former smoker	783 (3.2)	28 (3.2)	131 (3.9)	34 (4.2)	
Nonsmoker	15,020 (60.5)	591 (68.1)	2596 (71.0)	667 (81.5)	
Missing	3600 (14.5)	113 (13.0)	327 (8.9)	82 (9.1)	
Body mass index (N=26,275)					<.01[a]
<20	1976 (9.3)	56 (7.2)	165 (4.9)	46 (5.6)	
20—25	10,888 (51.0)	370 (47.9)	1354 (40.6)	329 (40.1)	
25—30	5587 (26.2)	224 (29.0)	1019 (30.6)	265 (32.3)	
>30	2897 (13.5)	123 (15.9)	796 (23.9)	180 (22.0)	
Missing	3479 (14.0)	95 (10.9)	324 (8.9)	80 (8.9)	
SIMD (N=29,054)					<.01[a]
1—5 (least deprived)	7186 (30.0)	187 (23.3)	940 (27.4)	217 (25.8)	
6—10 (most deprived)	16,796 (70.0)	617 (76.7)	2486 (72.6)	625 (74.2)	
Missing	845 (3.4)	64 (7.3)	232 (6.3)	58 (6.4)	
Diabetes mellitus (any)					<.01[a]
Yes	302 (1.2)	22 (2.5)	84 (2.3)	26 (2.9)	
No	24,525 (98.8)	846 (97.5)	3574 (97.7)	874 (97.1)	
Antepartum hemorrhage					<.01[a]
Yes	1811 (7.3)	80 (9.2)	312 (8.5)	53 (5.9)	
No	23,016 (92.7)	788 (90.8)	3346 (91.4)	847 (94.1)	
Preeclampsia					<.01[a]
Yes	2877 (11.6)	140 (16.1)	479 (13.1)	96 (10.7)	
No	21,950 (88.4)	728 (83.9)	3179 (86.9)	804 (89.3)	
Threatened miscarriage					.22
Yes	3974 (16.0)	145 (16.7)	617 (16.9)	163 (18.1)	
No	20,853 (84.0)	723 (83.3)	3041 (83.1)	737 (81.9)	

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TABLE 2
Second pregnancy demographic, obstetrical, and perinatal characteristics according to mode of birth in first pregnancy; N=30,253 (continued)

	Mode of birth in first pregnancy, n (%)				
Second pregnancy outcome N=30,253	Vaginal birth N=24,827 n (%)	Elective CD N=868 n (%)	First-stage CD N=3658 n (%)	Second-stage CD N=900 n (%)	P value
Labor type					<.01[a]
Spontaneous	18,611 (75.0)	317 (36.5)	1411 (38.6)	396 (44.0))	
Induced	5598 (22.5)	137 (15.8)	514 (14.1)	69 (7.7)	
Elective CD	618 (2.5)	414 (47.7)	1733 (47.4)	435 (48.3)	
Neonatal unit admission					<.01[a]
Yes	1508 (6.1)	85 (9.8)	372 (10.2)	97 (10.8)	
No	23,319 (93.9)	783 (85.0)	3286 (89.8)	803 (89.2)	
Birthweight					.50
Mean (SD)	3485.2 (527.1)	3399.9 (528.7)	3479.0 (541.4)	3468.5 (536.0)	
Missing	9	0	1	0	
Preterm prelabor rupture of membranes	Numbers not included because of small counts in CD groups				0.79
Yes					
No					
Blood loss					
Median	150	360	400	400	<.01[a]
Mode of second birth					<.01[a]
Vaginal birth	23,370 (94.1)	287 (33.1)	1020 (27.9)	283 (31.4)	
Elective CD	614 (2.5)	414 (47.7)	1730 (47.3)	434 (48.2)	
First stage CD	712 (2.9)	167 (19.2)[b]	862 (23.6)	150 (16.7)	
Second stage CD	131 (0.5)	—	46 (1.3)	33 (3.7)	
Interpregnancy interval (mo)					
Median	31	32	32	32	<.01[a]

CD, cesarean delivery; *SIMD*, Scottish Index of Multiple Deprivation.

[a] Statistically significant; [b] Includes first- and second-stage CD because of small numbers of second-stage CD for censoring purposes.

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birth, particularly vaginal birth (including assisted vaginal birth). However, the absolute risk of PTB was low in this population, and most PTBs occurred at >34 weeks' gestation.

Results in the context of what is known

As with all observational research, causation cannot be proven from this study. However, this study is a strong addition to the body of research that suggests that having a previous CD appears to change the risk for sPTB in future pregnancies.[8–10,14] Another Scottish population-based study reported a 3-fold

increased risk of sPTB after CDfd.[14] However, the authors suggest that CD in the first stage of labor is not associated with sPTB,[14] which contradicts our findings but may also be due to their smaller sample size.[14] Canadian research found a 2-fold increased risk of sPTB at <32 weeks' gestation and 1.5-fold for sPTB at <37 weeks' gestation.[10] In our data, we found a lesser difference between groups when only PTB <34 weeks was considered, suggesting that late PTB may have accounted for the significant association observed with sPTB and CDfd. This is of clinical interest because the implications of late PTB are considerably lesser for the

neonate compared with birth at earlier gestations.[4] However, the Canadian study[10] included births from 20 to 24 weeks, which may account for the increased risk of PTB <32 weeks. Williams et al[14] suggested that the risk of sPTB increased with increasing cervical dilatation. Similarly, Wood et al[10] found that the rate of sPTB birth was higher in the group with 9- to 10-cm dilatation compared with those with 0- to 4-cm dilatation at the time of initial CD.

Quiñones et al[28] hypothesized that increased duration of the second stage could lead to a subsequent risk of PTB. The rate of sPTB in a subsequent

TABLE 3

Odds ratio of preterm birth and spontaneous preterm birth (24—36 weeks) in second pregnancy according to mode of birth in first pregnancy (complete case)

Outcome	Unadjusted OR (95% CI)	Adjusted[a] OR (95% CI)	P value
Second-stage CD vs all other births			
Preterm birth (24—36 wk)	1.53 (1.14—2.06)	2.05 (1.48—2.85)[a]	<.01[b]
Spontaneous preterm birth (24—36 wk)	2.63 (1.82—3.81)	3.31 (2.17—5.05)[a]	<.01[b]
Second-stage CD vs vaginal births			
Preterm birth (24—36 wk)	1.53 (1.14—2.06)	2.13 (1.53—2.97)[a] 2.65 (1.83—3.82)[c]	<.01[b] <.01[b]
Spontaneous preterm birth (24—36 wk)	2.79 (1.93—4.05)	3.70 (2.42—5.67)[a] 5.37 (3.40—8.48)[c]	<.01[b] <.01[b]
Second-stage CD vs elective CD			
Preterm birth (24—36 wk)	1.23 (0.80—1.90)	1.68 (1.01—2.80)[a] 1.63 (0.98—2.73)[d]	.05 .06
Spontaneous preterm birth (24—36 wk)	1.55 (0.85—2.85)	1.90 (0.90—4.02)[a] 1.76 (0.83—3.28)[d]	.09 .14
Second-stage CD vs first-stage CD			
Preterm birth (24—36 wk)	1.59 (1.13—2.24)	1.94 (1.32—2.83)[a] 1.94 (1.34—2.85)[d]	<.01[b] <.01[b]
Spontaneous preterm birth (24—36 wk)	1.64 (1.06—2.52)	1.83 (1.12—2.99)[a] 1.86 (1.14—3.05)[d]	.02[b] .01[b]
All CD vs vaginal births			
Preterm birth (24—36 wk)	1.10 (0.94—1.28)	1.25 (1.05—1.50)[a]	.01[b]
Spontaneous preterm birth (24—36 wk)	1.91 (1.57—2.35)	2.08 (1.64—2.64)[a]	<.01[b]
Emergency CD (any-stage labor) vs vaginal births			
Preterm birth (24—36 wk)	1.07 (0.91—1.27)	1.27 (1.05—1.53)[a]	.02[b]
Spontaneous preterm birth (24—36 wk)	1.94 (1.57—2.41)	2.18 (1.70—2.81)[a]	<.01[b]
First-stage CD vs vaginal births			
Preterm birth (24—36 wk)	0.96 (0.80—1.16)	1.09 (0.87—1.36)[a]	.45
Spontaneous preterm birth (24—36 wk)	1.71 (1.33—2.20)	1.82 (1.36—2.44)[a]	<.01[b]

BMI, body mass index; *CD*, cesarean delivery; *CI*, confidence interval; *OR*, odds ratio; *SIMD*, Scottish Index of Multiple Deprivation.

[a] Adjusted for: maternal age, diabetes mellitus, BMI, smoking, preeclampsia, antepartum hemorrhage, socioeconomic deprivation (SIMD 2016), year of delivery, and interpregnancy interval (all in second pregnancy); [b] Statistically significant; [c] Adjusted for: pregnancy 1: antepartum hemorrhage, preeclampsia, length of first stage of labor, length of second stage of labor; pregnancy 2: maternal age, diabetes mellitus, BMI, smoking, preeclampsia, antepartum hemorrhage, socioeconomic deprivation (SIMD 2016), year of delivery, and interpregnancy interval; [d] Adjusted for: pregnancy 1: antepartum hemorrhage and preeclampsia; pregnancy 2: maternal age, diabetes mellitus, BMI, smoking, preeclampsia, antepartum hemorrhage, socioeconomic deprivation (SIMD 2016), year of delivery, and interpregnancy interval.

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pregnancy was increased among patients with a second stage of labor >180 minutes in the previous pregnancy for all birth types, but there was no association when vaginal births were analyzed alone, although CDfd led to a 3-fold increased risk of sPTB in a subsequent pregnancy.[28] Conversely, 2 studies found no significant difference in duration of initial second stage of labor or in subsequent risk of sPTB between women with and without an initial CDfd.[10] In our findings, when lengths of the second and first stage of labor and first-pregnancy APH and preeclampsia were included in the multivariate models, the size of the association between CDfd and sPTB increased substantially. However, there were a significant number of missing values for length of second stage, and therefore the significant difference in length of the second stage between those who had an initial CDfd and those with a vaginal birth must be interpreted with caution.

Our findings from a prolonged historic cohort suggest that the number of women having a CDfd has not significantly changed from 1976 to 2016. This is in direct contrast to work published previously.[13,16—18] This may be due to Aberdeen having traditionally offered multiple modalities of assisted vaginal birth to the present day (including rotational forceps births and breech vaginal births), and the high proportion of assisted vaginal births among the first vaginal

TABLE 4
Comparison of subsequent outcome of preterm birth and spontaneous preterm birth after first-pregnancy vaginal births, stratified according to spontaneous and assisted vaginal births vs second-stage (full-dilatation) cesarean delivery

First mode of birth	Second pregnancy outcome—preterm birth (N=25,725)			
	Preterm birth (N=929) n (%)	Term birth (N=24,796) n (%)	Unadjusted OR (95% CI)	Adjusted[a] OR (95% CI)
Spontaneous vaginal birth	596 (3.7)	15,157 (96.3)	1.0	1.0
Forceps	175 (3.2)	5306 (96.8)	0.84 (0.71—1.00)	1.01 (0.78—1.31)
Kielland	39 (3.0)	1263 (97.0)	0.79 (0.57—1.09)	1.03 (0.61—1.75)
Ventouse	57 (2.7)	2028 (97.3)	0.72 (0.54—0.94)	0.84 (0.61—1.15)
Vaginal breech birth (including assisted)	14 (6.9)	190 (93.1)	1.87 (1.08—3.24)[b]	1.97 (0.95—4.10)
CD at full dilatation	48 (5.3)	852 (94.7)	1.43 (1.06—1.94)[b]	2.93 (1.98—4.34)[b]
First mode of birth	Second pregnancy outcome—spontaneous preterm birth (N=19,005)			
	Spontaneous preterm birth (N=600) n (%)	Term birth (N=18,405) n (%)	Unadjusted OR (95% CI)	Adjusted[a] OR (95% CI)
Spontaneous vaginal birth	396 (3.3)	11,755 (96.7)	1.0	1.0
Forceps	109 (2.8)	3742 (97.2)	0.87 (0.70—1.07)	1.02 (0.73—1.42)
Kielland	25 (2.7)	900 (97.3)	0.83 (0.55—1.24)	0.99 (0.49—2.01)
Ventouse	27 (1.8)	1490 (98.2)	0.54 (0.36—0.80)	0.66 (0.42—1.04)
Vaginal breech birth (including assisted)	11 (6.7)	154 (93.3)	2.12 (1.14—3.94)[b]	1.96 (0.85—4.51)
CD at full dilatation	32 (8.1)	364 (91.1)	2.61 (1.79—3.80)[b]	5.17 (3.15—8.48)[b]

CD, cesarean delivery; *CI*, confidence interval; *OR*, odds ratio.

[a] Adjusted for: pregnancy 1=length of first-stage labor, length of second-stage labor, antepartum hemorrhage, preeclampsia, birthweight, smoking, maternal diabetes mellitus; pregnancy 2=antepartum hemorrhage, preeclampsia, year of birth, interpregnancy interval, age at birth, body mass index, socioeconomic deprivation (Scottish Index of Multiple Deprivation 2016); [b] Statistically significant.

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births in this sample. A previous study conducted using AMND data suggested that the rate of unplanned CD has increased between 1988 and 2012, and that lowered clinical thresholds and shorter labor durations before decision for intrapartum CD may be responsible.[19]

Clinical implications

Obstetrical skills in assisted vaginal births have been declining, particularly in the use of forceps and rotational forceps.[30,31] If the association presented in this research is causative, this suggests that obstetricians need to retain their skills in assisted vaginal birth as well as skills in manual rotation to ensure that there are alternatives to CDfd. Women may need to be informed of the increased risk of sPTB with a CDfd as part of shared decision-making and informed consent in discussions on intrapartum mode of birth. A recent meta-analysis[32] suggested that

maternal risks of adverse outcomes such as postpartum hemorrhage were lower with Kielland forceps than with CDfd; therefore, retention of obstetrical skills in instrumental births including rotational forceps needs to be reevaluated.

In addition, devices and surgical techniques used to assist with the birth of the impacted head at CDfd could reduce the chance of cervical injury at the time of CDfd and the subsequent risk of sPTB. A prospective cohort study or randomized controlled trial to determine the impact of using such devices or techniques on the outcome of subsequent sPTB is needed. In many institutes, it is standard practice to make a higher uterine incision at the time of CDfd, but there is minimal research on the impact of location of incision on the subsequent risk of sPTB.

In this population, women who had an initial CDfd were at 20-fold risk of

having another CDfd in the second birth, and >50-fold risk of having an elective CD in the second pregnancy, with only 31% of women having a vaginal birth after a CDfd in the first pregnancy. This is important to discuss with women as part of shared decision-making in future pregnancy, but is also relevant in interpreting the results of this research given that very few women appear to attempt vaginal birth after CDfd in the first term pregnancy.

Research implications

Progesterone has been reported in a recent network analysis[33] as the favored treatment to prevent sPTB, but no published studies have investigated treatments according to the cause or individualized risk factors for PTB. Given that different causes, such as injury to the cervix at time of CDfd, may

respond to different treatments, research needs to focus on understanding individual cause(s) and aligning preventative treatments to the underlying individualized pathology, for example, previous CDfd. An ongoing prospective study (CRAFT [Cerclage after full dilatation caesarean section])[34] aims to understand the mechanism of increased risk of sPTB after CDfd using ultrasonographic cervical length measurements, fetal fibronectin, and magnetic resonance imaging, which will hopefully improve our understanding and our ability to predict those at increased risk of sPTB after CDfd. Research is needed to understand if improving intrapartum labor management could reduce the rates of failure to progress in the second stage of labor. A large Swedish cohort suggested that sPTB was increased when the fetal head had a lower station at the time of CD, but that lower uterine segment thickness, type of incision used on the uterus at time of CD, and 1- or 2-layer closure did not affect the risk of subsequent PTB.[35] A prospective study to measure the distance from the cervix to the CD scar niche in a future pregnancy and the depth of the scar niche may provide new insight on sonographic risk factors in the subsequent pregnancy. It remains uncertain if having a CDfd after a failed assisted vaginal birth increases the risk of sPTB compared with women who did not have an attempt at instrumental vaginal birth. Further research is vital to understand changes in CD rates, specifically the rates of CD in the first and second stage of labor, the indications for those CDs, and the role of maternal choice.

Strengths and limitations

This was a large observational study that substantially adds to the body of evidence on the risk of subsequent sPTB after CDfd, and includes a detailed assessment of potential confounding factors. We performed analyses adjusted for preeclampsia and APH in the first pregnancy because both have been associated with subsequent risk of PTB in a previous study.[36] We adjusted for year of birth in the multivariate analyses aiming to reduce any confounding caused by change in practice over time.

One of the strengths of this study is the use of AMND as the data source. The AMND is a validated and high-quality data source of routinely collected hospital data, having been used for multiple high-quality observational studies with access to numerous covariate data.[21] The outmigration rate from the Aberdeen area is low (3.8%), meaning that most women remain in Aberdeen for their pregnancies,[21] making AMND an ideal data source to study subsequent pregnancy outcomes given that most women remain in the area for all of their pregnancies. Other strengths of this study include defining sPTB and differentiating each mode of initial birth, including individual types of assisted vaginal birth such as breech delivery. We considered it clinically relevant to investigate CDfd compared with all other modes of birth and with individual modes of birth, and believe that this is a strength of this research. However, performing multiple analyses does lead to risk of type 1 error, which we acknowledge and highlight.

However, this study has limitations. By including only primigravid women, the results may not be generalizable to women who have a CDfd in a second or subsequent pregnancy. The results may not be generalizable to other populations, particularly those with different obstetrical practice compared with the United Kingdom. Studying subsequent pregnancy outcomes involves the possibility of a proportion of second pregnancies not being captured in the selected study period; this is of particular concern for women with the most recent first pregnancies for whom a second pregnancy may not have yet occurred. A potential limitation is the method by which CDfd was recorded within the AMND given that it was defined according to the documentation of the date and time of second stage of labor onset. This meant that the exact cervical dilatation measurement at time of CD was not documented for first-stage CD, and that women who had not been examined immediately before CD could have been miscategorized as having first-stage CD. We believe this risk to be small given that standard

clinical practice is to examine women before CD in labor to check for full dilatation in this hospital. Another limitation is that we did not include indication for CD in the analysis. Other risk factors for sPTB such as infection, previous cervical treatment or surgery, previous myomectomy, or maternal drug use were not included. However, such factors may not be true confounders given that, although associated with sPTB, they are not known to be associated with CDfd. The overall rate of PTB was lower than expected in this sample. This may be due to the eligibility criteria selected for the study. Ethnicity was not included as a potential confounding factor and could affect the generalizability of the results. From census data we know that Aberdeen is more diverse than Scotland as a whole, which will be captured in this population-based study, although overall Aberdeen has a predominantly White Scottish population.[37] The proportion of PTBs <28 weeks was small; therefore, we did not include this as a separate outcome. We did not have information on cervical length in the second pregnancy. The historic nature of this cohort is a potential limitation, and data collection for this study ceased in 2017. We were not able to differentiate the second stage in terms of passive and active pushing when the CD was performed. Fetal anomalies may also influence the risk of sPTB, but information on this was not available in our data set.

Conclusions

CDfd in the first pregnancy is significantly associated with increased risk of sPTB in the subsequent pregnancy. ∎

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SUPPLEMENTAL TABLE
Odds ratios of preterm birth and spontaneous preterm birth (24—36 weeks) in second pregnancy according to mode of birth in first pregnancy, with imputed values for smoking, deprivation, and body mass index (BMI) in second pregnancy, and adjusted for age, diabetes mellitus, BMI, smoking, preeclampsia, antepartum hemorrhage, deprivation, year of delivery, and interpregnancy interval (N=30,253)

Outcome	Adjusted[a] OR (95% CI)	P value
Second-stage CD vs all other births		
Preterm birth (24—36 wk)	1.84 (1.62—2.08)	<.01[b]
Spontaneous preterm birth (24—36 wk)	3.06 (2.61—3.59)	<.01[b]

CD, cesarean delivery; *CI*, confidence interval; *OR*, odds ratio.

[a] Adjusted for age, diabetes, BMI, smoking, pre-eclampsia, antepartum haemorrhage, deprivation, year of delivery and interpregnancy interval; [b] Statistically significant.

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