The effect of mode of delivery and duration of labour on subsequent pregnancy outcomes: a retrospective cohort study

Kimberly D Van Winsen[1], Makrina D Savvidou,[2,3] Phil J Steer[2]

[1]Specialist Registrar, Department of Obstetrics and Gynaecology, Chelsea and Westminster Hospital, London, UK.

[2]Academic Department of Obstetrics and Gynaecology, Department of Metabolism, Digestion and Reproduction, Imperial College London, Chelsea & Westminster Hospital, London, UK

[3]Fetal Medicine Unit, Chelsea & Westminster Hospital, London, UK

Correspondence:

Dr Kimberly D Van Winsen

Specialist Registrar in Obstetrics and Gynaecology

Chelsea & Westminster Hospital

369 Fulham Road

London SW10 9NH, UK

Tel: 02033158000

E-mail: k.vanwinsen@nhs.net

Running Title: Effect of mode of delivery and duration of labour on subsequent pregnancy outcomes

Abstract

Objective To assess if delivery mode and duration of labour in a first labour of spontaneous onset is associated with gestational length, delivery mode 3and neonatal outcome in the subsequent pregnancy.

Study Design Retrospective analysis of prospectively collected data.

Setting 15 Maternity units in North West London (1988 to 2000).

Population 30,840 women with spontaneous onset of labour in pregnancy 1 and a subsequent birth reported in the same database.

Methods Assessment of outcomes by mode of delivery in pregnancy 1, restricting the analysis to the difference in the gestational length between pregnancy 1 and 2.

Main Outcome Measures Gestational length, mode of delivery and neonatal unit admission in pregnancy 2.

Results Caesarean section (CS) in the first or second stage of labour in pregnancy 1 was associated with pregnancy 2 being a median of 5 and 8 days shorter and a preterm birth rate of 6.0% and 10.1% respectively, whereas following a spontaneous or instrumental birth in pregnancy 1 the median duration was similar, with preterm delivery rates of 4.5% and 3.9%. 56.2% of women with a CS in pregnancy 1 had a repeat CS and 12.5% of their babies were admitted to neonatal unit, compared with 5.3% of women with vaginal birth. Longer labours were associated with shorter gestations in pregnancy 2.

Conclusions Compared to vaginal birth, an emergency CS in the first term pregnancy is associated with a shorter gestational length, increased rate of repeat CS and increased risk of NNU admission in the next pregnancy.

Funding: Nil

Keywords; caesarean section, preterm labour, early-term, mode of delivery**,** labour, gestation, neonatal outcome

Tweetable abstract An emergency caesarean section in the first term pregnancy affects the duration and outcome of the next pregnancy.

Introduction

Preterm birth (PTB) is the leading cause of perinatal mortality and morbidity.[1] The accepted definition of 'preterm' is less than 37 completed weeks of pregnancy, however the improvement in neonatal condition at birth continues up to 40 weeks.[2] Gestations of 37 to 38+6 weeks have been described as 'early term' and are associated with increased rates of respiratory morbidity and neonatal unit (NNU) admissions when compared to births at 40 to 41 weeks.[3] The variation in gestational length is multifactorial, and naturally occurring influences include maternal age, race, smoking, medical conditions, and socio-economic factors. The gestational length in successive pregnancies is highly correlated[4], which suggests that constitutional factors are important.

Factors which weaken or damage the cervix, such as infection or previous trauma, are associated with spontaneous preterm and early-term birth.[5] Caesarean section (CS) at full dilatation and prolonged second stage of labour in the first pregnancy have been suggested in some small studies [6,7] (although not all)[8] to reduce the length of gestation in subsequent pregnancies. It has been hypothesised that this reduction in gestational length is in part attributed to cervical weakening by direct trauma.[9] Previous studies have reported only on dichotomised variables (e.g. preterm vs term births) which obscures differences in distribution and does not indicate variation within the 'term' group, which may be of clinical significance.

The rates of CS are rising globally, with 21% of babies born by CS in 2015, compared with 12% in 2000, with an estimated 4% annual rise[10]. Although advancement of surgical and anaesthetic techniques make it a relatively safe procedure, it remains a major surgical intervention which carries both short and long-term maternal and neonatal morbidity. CS is associated with increased intraoperative blood loss, increased rates of venous thromboembolism, damage to surrounding organs, infection and post-operative pain.[11] There

may also be long term harms to babies born by CS, possibly secondary to different physical, hormonal and bacterial exposures at the time of birth.[2] Several studies have reported that a CS in nulliparous pregnancy has an adverse effect on neonatal outcomes in subsequent pregnancies.[6,8]

The aim of this large, retrospective study was to assess the effect of mode of delivery and duration of a first singleton labour of spontaneous onset on the gestational length, mode of delivery and neonatal outcome in the subsequent pregnancy, using the highly validated database of the North West Thames region.

Methods

Data Collection

Anonymised data of 585,291 deliveries in 15 London Maternity units in the North West Thames region were collected between 1988 and 2000 inclusive. Data on 301 variables were entered by trained clerks or midwives for each pregnancy, from the first antenatal visit until 28 days post-partum. These data were extensively cleaned and have been validated by multiple studies, providing a large, reliable and high-quality obstetric database.[4]

As the data were anonymised, it was not possible to identify consecutive pregnancies by name or hospital number. Instead, first (parity 0) and second (parity 1) pregnancies to the same women were matched using the mother's date of birth, the hospital in which they gave birth, their ethnic group, and their height (to within 3 cm to allow for small differences in conversions from feet and inches to cm). Importantly, the data on each pregnancy were collected in equal detail and with equal accuracy. All women within the database who were nulliparous and had a singleton, phenotypically normal pregnancy with spontaneous onset of labour, and who had a subsequent birth recorded on the same database, were included in the current study.

Gestational length was calculated as the duration of pregnancy from the first day of the last menstrual period (LMP) in women who were certain of their dates and had a regular 28 days' cycle. Otherwise, the gestational length was determined from the fetal biparietal diameter on an ultrasound measurement made before 24 weeks gestation. Where there was a discrepancy of more than 14 days between the expected date of delivery (EDD) calculated by the LMP and ultrasound, the EDD based on the mid-trimester ultrasound scan was used. Additional plausibility checks were conducted and where there was a discrepancy of greater than 14 days between the estimate of gestational age at birth and the gestational age calculated antenatally, a further system enquiry was raised and implausible cases removed. Importantly, the duration of each pregnancy was calculated in days, rather than being rounded to the nearest week, which can obscure important differences in gestational length distribution.

Mode of delivery was categorised as normal vaginal birth (including spontaneous and assisted vaginal breech), instrumental vaginal birth (ventouse or forceps), emergency CS in the first or second stage of labour, and elective CS.

Statistical analysis

Data are expressed as median (interquartile range) or n (%), as indicated. In particular, duration of gestation was expressed as median, mode and interquartile range. Mann-Whitney's U test and chi-square x^2 were used to compare numerical and categorical variables, respectively. There was an initial assessment of the outcomes by mode of delivery in pregnancy 1 restricting the analysis to the difference in the gestational length between pregnancy 1 and pregnancy 2. This controls for the high level of correlation between the durations of first and second pregnancies.[4] The effect on the duration of pregnancy of variables associated with maternal health, such as medical history, weight, smoking and

social status are largely controlled for when the inter-pregnancy interval is short, as it was bound to be due to the constraints of the study period duration.

Further analysis compared the outcomes (mode of delivery, gestational length, neonatal positive pressure resuscitation and neonatal unit admission) of pregnancy 2 by mode of delivery in pregnancy 1 (normal birth, instrumental birth, CS in the first or second stage of labour). Relative risks were calculated.

Analysis was further stratified by analysing only pregnancies with a spontaneous onset in both pregnancies and limiting analysis to cases where the first birth was at term (≥37 weeks gestation). Spearman's Rho correlation and linear regression were used to assess the influence of maternal characteristics associated with the duration of pregnancy 2 other than the mode of delivery. Data were analysed using the Statistical Package for Social Sciences (SPSS) version 26 (IBM).

Results

32,595 first and second pregnancies with mode of delivery recorded were matched and 30,840 (94.6%) had a first birth following spontaneous onset of labour. In pregnancy 1, 28,594 (92.7%) women had a vaginal birth (normal birth n= 22208; 72% and instrumental birth n= 6386; 20.7%) and 2,246 (7.3%) had an emergency CS, either in the first stage (n=1790; 5.8%) or second stage (n=456; 1.5%) of labour. Maternal demographic, pregnancy characteristics and mode of delivery in pregnancy 2 are shown in Table 1.

The duration of the first and second pregnancy is strongly correlated[4] and analysing the difference in the length between pregnancy 1 and pregnancy 2 uses each woman as her own control. The duration of pregnancy is associated with many maternal variables, but most (e.g. maternal height and weight, social status, smoking and past medical history such as

diabetes and hypertension) are similar between pregnancies; at least in the studied population as the median inter-pregnancy interval was only 20 months with a 75th centile of 30 months. The duration of pregnancy 1 was significantly correlated with maternal age, height and weight at booking, White European and Black Caribbean race, single unsupported mother, smoking, the use of oxytocin and of epidural analgesia in labour ($p<0.005$ to allow for multiple testing) (Supplementary Table S1). However, when assessing the correlation with the difference in gestational length between pregnancy 1 and pregnancy 2, only oxytocin augmentation and uptake of epidural analgesia remained significant (Supplementary Table S2). Both oxytocin augmentation and use of oxytocin became non-significant ($p>0.01$) when included in a multivariable regression with mode of delivery (Supplementary table S3).

The rates of instrumental birth, emergency CS and elective CS in pregnancy 2 were all significantly higher ($p<0.005$) when there had been intervention in pregnancy 1, although the biggest effect was seen with CS in pregnancy 1 (Table 1). Women who underwent a CS in the first or second stage of labour in pregnancy 1 had a significantly shorter duration of pregnancy 2 than women who had a vaginal birth in pregnancy 1 (Table 2). Gestational length was shorter in pregnancy 2 compared with pregnancy 1 following intervention in pregnancy 1 even after excluding women undergoing elective repeat CS in pregnancy 2 by only including births of spontaneous onset in pregnancy 2 (n=25,854). Caesarean section in the first or second stage of labour in pregnancy 1 was associated with a significantly higher preterm delivery rate in pregnancy 2, which also held true when only cases with spontaneous onset of labour in pregnancy 2 were considered (relative risk (RR)= 1.71 and 3.28 respectively; $p<0.001$) (Table 3). Compared to normal vaginal birth, having a CS in the second stage in pregnancy 1 resulted in the most marked increase in preterm delivery (10.3% vs 3.2%) but there was also an increase in early term (37-38^{+6} weeks) delivery (25.4% vs 17.6%; RR=1.15; $p<0.001$).

Investigation of the duration of the first and second stage in pregnancy 1 revealed a small but statistically significant association of longer labours with a shorter gestational length in pregnancy 2 (Supplementary Tables S3 and S44). The regression equation for the duration of pregnancy 2 according to the length of the first stage of labour was: change in pregnancy duration = 1.682 – (length of first stage *0.221). This computes to 1.461 days longer than average gestational length of pregnancy 2 for a one hour first stage, and 0.528 days shorter gestational length of pregnancy 2 for ten hours of first stage, i.e. a longer first stage of labour shortens the length on gestation in the subsequent pregnancy. For the length of the second stage, the equation was: change in pregnancy duration = 0.276 - (length of second stage*0.550). This implies –0.274 days and -1.374 days shorter gestational length for one and three hours of second stage, respectively (i.e. a longer second stage shortened the gestational length in the subsequent pregnancy).

Neonatal outcomes were assessed as the need for positive-pressure ventilation and as the need for admission to a neonatal unit (NNU). Compared with normal vaginal birth, all forms of intervention in pregnancy 1 were associated with a higher rate of admission to NNU in pregnancy 2, even if cases of preterm delivery (<37 weeks) that were likely to have resulted in NNU admission due to prematurity, were excluded (Table 3). Admission to the NNU was higher at both <37 weeks (52.2%, RR 17.02; 95% CI 15.57 to 18.61 p<0.0001) and 37-38+6 weeks (6.1%, RR 1.98; 95% CI 1.75 – 2.24 p<0.0001) when compared to >39 weeks (3.1%). The effect of gestation on the need for positive pressure ventilation is only seen before 37 weeks, where 21.9% (RR 3.1246; 95% CI 2.8 to 3.48 p<0.0001) required PPV at <37 completed weeks, 6.6% (RR 0.997; 95% CI 0.89 – 1.1 p = 0.97) at 37 – 38+6 weeks, and 7% at 39 or more weeks.

Discussion

Main Findings

This study has shown that, compared to vaginal birth, an emergency CS in the first or second stage of a first term pregnancy of spontaneous onset is associated with a shorter gestational length and a higher rate of preterm and early-term birth in the subsequent pregnancy, leading to an increased risk of admission to a NNU. We have also demonstrated a significant inverse correlation between longer (first and second stage) labours and the length of subsequent pregnancy.

Use of oxytocin or epidural analgesia in labours resulting in CS, as well as prolonged first and second stages of labour in the first pregnancies, were associated with shorter gestational length in the next pregnancy. It is probable that use of oxytocin and/or epidural analgesia are surrogate markers of prolonged, difficult and dysfunctional first labours resulting in CS; the association was largely negated by controlling for mode of delivery.

In our study population, 56% of women who underwent a CS in their first pregnancy had a repeat CS in their next pregnancy. When taking informed consent prior to performing CS, increased risk of repeat caesarean section and earlier birth and its associated neonatal morbidity should be discussed in addition to the previously well described maternal complications.

Strengths and Limitations

This study has high statistical power, with a total of 30,840 women included. The dataset is of established high quality and has been extensively validated in previous studies. Although the data were collected between 1988 and 2000, the importance of the findings has been emphasised by subsequently rising rates of elective caesarean section. We have analysed gestational length as a pseudo-continuous variable in days, in contrast to previous studies, which defined gestation in dichotomous terms as either ‘term’ or ‘preterm’, which obscures differences in distribution.

Although CS in the first stage of labour was recorded in the database, we do not have information on the exact cervical dilatation at which the caesarean section was performed. It is plausible that there will be a dose-response relationship between cervical dilatation at the time of the first CS and a reduction in the duration of a subsequent pregnancy.

Interpretation

Several studies have demonstrated that CS in the second stage of labour is associated with an increase in the risk of late miscarriage and early spontaneous preterm birth in the next pregnancy.[13,14] Our study has shown that the increased risk of preterm birth and early-term birth also extends to women with a previous CS in the first stage of labour. The median length of gestation in the second pregnancy was 5 and 7 days shorter if a CS in the first pregnancy was performed in the first or second stage of labour, respectively, compared to women with a previous vaginal delivery. This was associated with an increased rate of subsequent preterm birth, early-term birth and an almost 2- and 4-fold increase in the rate of NNU admission respectively.

Although preterm birth is defined as <37 weeks, Bates et al. (2014) showed that neonatal morbidity in babies born between 36 and 38+6 weeks is higher when compared to babies born after 39 weeks.[2] Early-term delivery (37^{+0}-38^{+6} weeks) is associated with increased neonatal and infant morbidity including respiratory distress syndrome, transient tachypnoea of the newborn, use of surfactant/ ventilator, pneumonia, respiratory failure, hypoglycaemia, 5-minute Apgar score <7 and mortality compared to neonates born ≥39 weeks of gestation.[15] This study highlights that even a relatively small reduction in gestational length may lead to increased neonatal morbidity, with an almost 2-fold increase in NNU admission for babies born between 37 – 38+6 when compared to >39 weeks. In accordance with this,

and in the absence of a fetal, maternal or obstetric indication for earlier birth, both ACOG and RCOG advise elective deliveries to be carried out from 39 weeks onwards.[15, 16]

The findings of this retrospective study suggest that multiple factors which may affect cervical integrity following the first term pregnancy and labour can lead to a shorter subsequent pregnancy. A major role of the cervix in pregnancy is to keep the fetus in-utero by providing mechanical strength/support and preventing infection.[17] CS, in both the first and second stage of labour, can cause cervical damage as a lower segment uterine incision can impinge on the upper part of the cervix. This is likely to be more pronounced in CS in advanced labour (>9cm cervical dilatation), where the cervix may be drawn into the hysterotomy closure, and accidental extensions of the uterine incision during the delivery of the fetal presenting part are more prevalent.[18]

Prolonged labours may also affect cervical integrity by resulting in structural damage to the cervical tissue [9,17] which could lead to defective cervical remodelling and an increased propensity for early-term or preterm labour in the subsequent pregnancy. Identification of an association between cervical dilatation at the time of CS and duration of first/ second stage of labour in the first pregnancy and the risk of subsequent PTB will help identify patients at high risk of PTB, stratify their care, and offer interventions that may reduce this risk. The prospective CRAFT (cerclage after full dilatation caesarean section) study, aiming to examine to role of in-labour CS in future PTB and the use of cervical cerclage in reducing this risk, is likely to reveal and clarify some of the associations between mode of delivery and future pregnancy outcomes.[19]

Conclusion

Identification and appropriate management of women at risk of preterm birth is a priority of the “Saving Babies Lives Care Bundle” in the UK.[20] This study has shown an association in nulliparous women between caesarean delivery, in the first or second stage of labour, its

duration and the rates of both preterm and early-term delivery in the next pregnancy. A CS in the first pregnancy is associated with a reduction in gestational length, a much increased rate of repeat CS and an increase in NNU admission in the next pregnancy. Further studies will be required to assess interventions that could be used to mitigate these risks.3

Acknowledgements

We would like to thank the units which contributed data to the Northwest Thames dataset, and the consultants in the participating hospitals, and the midwives who entered the data, without which this analysis could not have been possible.

Disclosure of Interest

Nil

Contribution of Authorship

The study was conceived and planned by MS and PS. The analysis of the data was performed by PS. The manuscript was written by KVW with input from all co-authors.

Ethics Approval

Governance Arrangements for Research Ethics Committees (GAfREC) was issued by the UK Health Departments in May 2011 and came into effect from 1 September 2011. This stated that "REC review is not required under the harmonised GAfREC for research limited to use of previously collected, non-identifiable information". On the 18th January 2012 we were informed by the Coordinator of the NRES Committee London that this exemption applied to the pseudo-anonymised NW Thames dataset used in the current study, and that consent for each specific project using it was no longer required.

Funding

Nil

References

1. López Bernal A. Overview. Preterm labour: mechanisms and management. BMC Pregnancy and Childbirth. 2007;7(S1).
2. Bates E, Rouse D, Tita A. Neonatal Outcomes After Demonstrated Fetal Lung Maturity Before 39 Weeks of Gestation. Obstetrics & Gynecology. 2011;117(5):1229.
3. McIntire D, Leveno K. Neonatal Mortality and Morbidity Rates in Late Preterm Births Compared With Births at Term. Obstetrics & Gynecology. 2008;111(1):35-41.
4. Ng K, Steer P. Prediction of an estimated delivery date should take into account both the length of a previous pregnancy and the interpregnancy interval. European Journal of Obstetrics & Gynecology and Reproductive Biology. 2016;201:101-107.
5. 8. Romero R, Dey S, Fisher S. Preterm labor: One syndrome, many causes. Science. 2014;345(6198):760-765.
6. Taylor L, Simpson J, Roberts C, Olive E, Henderson‐Smart D. Risk of complications in a second pregnancy following caesarean section in the first pregnancy: a population‐based study. Medical Journal of Australia. 2005;183(10):515-519.
7. Wood S, Tang S, Crawford S. Cesarean delivery in the second stage of labor and the risk of subsequent premature birth. American Journal of Obstetrics and Gynecology. 2017;217(1):63.e1-63.e10.

8. Huang X, Lei J, Tan H, Walker M, Zhou J, Wu Wena S. Cesarean Delivery for First Pregnancy and Neonatal Morbidity and Mortality in Second Pregnancy. Obstetrical & Gynecological Survey. 2012;67(2):81-82.
9. 12. de la Torre L, González-Quintero V, Mayor-Lynn K, Smarkusky L, Hoffman M, Saab A et al. Significance of accidental extensions in the lower uterine segment during cesarean delivery. American Journal of Obstetrics and Gynecology. 2006;194(5):e4-e6.
10. The Lancet. Stemming the global caesarean section epidemic. The Lancet. 2018;392(10155):1279.
11. Royal College of Obstetricians and Gynaecologists. Caesarean Section - Consent Advice No. 7. [Online] RCOG; 2009. Available at: https://www.rcog.org.uk/globalassets/documents/guidelines/consent-advice/ca7-15072010.pdf
12. Zhang X, Kramer M. Variations in Mortality and Morbidity by Gestational Age among Infants Born at Term. The Journal of Pediatrics. 2009;154(3):358-362.e1.
13. Vyas N, Vink J, Ghidini A, Pezzullo J, Korker V, Landy H et al. Risk factors for cervical insufficiency after term delivery. American Journal of Obstetrics and Gynecology. 2006;195(3):787-791.
14. Watson H, Carter J, David A, Seed P, Shennan A. Full dilation cesarean section: a risk factor for recurrent second-trimester loss and preterm birth. Acta Obstetricia et Gynecologica Scandinavica. 2017;96(9):1100-1105.
15. ACOG Committee Opinion No. 765: Avoidance of Nonmedically Indicated Early-Term Deliveries and Associated Neonatal Morbidities, 2019 Feb;133(2):e156-e163
16. Royal College of Obstetricians and Gynaecologists. Birth After Previous Caesarean Birth. Green-top Guideline No. 45. [Online] RCOG; 2015. Available at: https://www.rcog.org.uk/globalassets/documents/guidelines/gtg_45.pdf

17. Chandiramani M, Shennan A. Cervical insufficiency: prediction, diagnosis and prevention. The Obstetrician & Gynaecologist. 2008;10(2):99-106.
18. Berghella V, Gimovsky A, Levine L, Vink J. Cesarean in the Second Stage: A Possible Risk Factor for Spontaneous Preterm Birth. Obstetric Anesthesia Digest. 2018;38(1):45-45.
19. Carlisle N, Glazewska-Hallin A, Story L, Carter J, Seed P, Suff N et al. CRAFT (Cerclage after full dilatation caesarean section): protocol of a mixed methods study investigating the role of previous in-labour caesarean section in preterm birth risk. BMC Pregnancy and Childbirth. 2020;20(1).
20. NHS England. Saving Babies' Lives Care Bundle. [Online] NHS England; 2019. Available at: https://www.england.nhs.uk/wp-content/uploads/2019/03/Saving-Babies-Lives-Care-Bundle-Version-Two-Updated-Final-Version.pdf

411

412

413

414

415

416

417

418

Table 1. Maternal demographic characteristics of the study participants in first pregnancy by mode of delivery in the first pregnancy (pregnancy 1).

Characteristics in pregnancy 1 **N= 30840**				
Maternal characteristics	**Normal vaginal birth** N = 22208	**Instrumental vaginal birth** N = 6386	**Caesarean section stage 1** N = 1790	**Caesarean section stage 2** N = 456
Maternal age (years)	25.96 (6)	27.48 (5)	27.40 (6)	27.92 (6)
Maternal height (cm)	163.06 (10)	162.49 (9)	160.04 (10)	161.19 (8)
Maternal weight (kg) at booking	61.60 (12.3)	61.97 (12.5)	62.64 (13.5)	62.99 (12.9)
Maternal BMI (kg/m^2) at booking	23.14 (3.9)	23.44 (4.07)	24.41 (4.82)	24.2 (4.13)
Smoking, n (%)	1886 (8.5)	1141 (17.9)	335 (18.7)	75 (16.4)
Race, n (%)				
White European	18137 (81.7)	5244 (82.1)	1331 (74.4)	368 (80.7)
Black African	252 (1.1)	41 (0.6)	52 (2.9)	7 (1.5)
Black Caribbean	281 (1.3)	50 (0.8)	24 (1.3)	8 (1.3)
South Asian	2982 (13.4)	876. (13.7)	324 (18.1)	59 (12.9)
East Asian	188 (0.8)	56 (0.9)	23. (1.3)	3 (0.7)
Mediterranean	137 (0.6)	38 (0.6)	8 (0.4)	6 (1.3)
Other	231 (1)	81 (1.3)	28 (1.6)	7 (1.5)
Single unsupported mother, n (%)	3647 (16.4)	733 (11.5)	200 (11.2)	47 (10.3)
Diabetes, n (%)				
GDM	82 (0.4)	40 (0.6)	14 (0.8)	5 (1.1)
Pre-existing	5 (0.02)	8 (0.8)	3 (0.2)	0 (0.0)
Cardiac Disease, n (%)				
Acquired	42 (0.2)	12 (0.2)	8 (0.4)	1 (0.2)
Congenital	123 (0.6)	53 (0.2)	11 (0.6)	5 (1.1)
Hypertensive disorders of pregnancy, n (%)	267 (1.2)	71 (1.1)	25 (1.4)	5 (1.1)
Oxytocin use, n (%)	7820 (35.2)	4079 (63.9)	961 (53.8)	286 (62.9)
Epidural use, n (%)	4128 (18.6)	3546 (55.5)	1004 (56.1)	305 (66.9)
Gestation at delivery in pregnancy 1 (days)	277.78 (12)	279.73 (12)	279.08 (14)	280.23 (12)
Preterm birth, n (%)	1222 (5.5)	267 (4.2)	107 (6.0)	18 (3.9)
Sex of the neonate, n (%)				
Male	11147 (50.2)	3442 (53.9)	1017 (56.8)	260 (57)
Female	11060 (49.8)	2944 (46.1)	773 (43.2)	196 (43)
Birthweight (gr)	3266 (595)	3369 (620)	3342 (758)	3532 (601)
Normal vaginal birth in pregnancy 2, n (%)	20944 (94.3)	5453 (85.4)	498 (27.8)	131 (28.7)

Instrumental vaginal birth in pregnancy 2, n (%)	500 (2.3)	549 (8.6)	281 (15.7)	73 (16.0)
Elective CS in pregnancy 2, n (%)	276 (1.2)	154 (2.4)	561 (31.3)	176 (38.6)
Emergency CS in labour in pregnancy 2, n (%)	488 (2.2)	230 (3.6)	450 (25.1)	76 (16.7)

[a] :Values are median (interquartile range) unless otherwise stated

Relative risk of CS in the second pregnancy, CS in the first pregnancy vs vaginal delivery in the first pregnancy = 14.00 (95% CI 13.09 to 14.98 p<0.0001) NNT 1.915 (95% CI 1.952 to 1.879)

Table 2. Mode of birth in Pregnancy 1 vs gestational length in Pregnancy 2 and difference in gestational length from Pregnancy 1.

		Duration of gestation in pregnancy 2 (days)	Difference in gestational length between pregnancy 1 and pregnancy 2 (days)
Mode of delivery pregnancy 1	**N**	**Median (Interquartile range)**	**Median (Interquartile range)**
Normal vaginal birth			
All cases	22208	280 (273-285)	0.0 (-7.0-7.0)
Spontaneous onset of labour P2	19296	279 (273-285)	0.0 (-6.0-7.0)
Term birth in pregnancy 1 and SOP2	18231	280 (274-285)	0.0 (-7.0-6.0)
Instrumental vaginal birth			
All cases	6386	280 (274-286)	-1.0 (-8.0-6.0)***
Spontaneous onset of labour P2	5276	280 (274-285)	-1.0 (-7.0-6.0)***
Term birth in pregnancy 1 and SOP2	5046	280 (275-285)	-1.0 (-8.0-5.0)***
Caesarean Section- 1st Stage			
All cases	1790	275 (269-283)***	-5.0 (13.0-4.0)***
Spontaneous onset of labour P2	1036	279 (273-284)	-2.0 (-9.0-6.0)***
Term birth in pregnancy 1 and SOP2	963	280 (274-285)	-2.0 (-9.0-5.0)***
Caesarean Section- 2nd Stage			
All cases	456	273 (267-280)***	-8.0 (-16.0-0.0)***
Spontaneous onset of labour P2	246	276 (267-282)***	-4.0 (-13.0-3.0)***
Term birth in pregnancy 1 and SOP2	232	276 (268-282)***	-4.5 (-13-1.0)***

Data are expressed as median (interquartile range), as indicated, and compared with normal vaginal birth using Mann-Whitney U test. *p<0.05, **p<0.005, ***p<0.0005.
P2: second pregnancy SOP2: spontaneous onset in Pregnancy 2, Term: birth ≥37 weeks

Table 3. Gestational age groups in Pregnancy 2 and neonatal outcomes by mode of delivery in Pregnancy 1.

		Gestational age at delivery in pregnancy 2			Neonatal outcome in pregnancy 2	
Mode of Delivery pregnancy 1	**N**	**<37 weeks**	**37-38^{+6} weeks**	**≥39 weeks**	**Positive pressure ventilation**	**Admission to Neonatal Unit**
Normal vaginal birth						
All cases	22208	999 (4.5)	4236 (19.1)	16973 (76.4)	1539 (6.9)	1121 (5.0)
Spontaneous onset of labour P2	19296	764 (4.0)	3566 (18.5)	14966 (77.6)	1231 (6.4)	815 (4.2)
Term birth in Pregnancy 1 and SOP2	18231	574 (3.2)	3203 (17.6)	14454 (79.3)	1124 (6.2)	678 (3.7)
Instrumental vaginal birth						
All cases	6386	246 (3.9) *	1114 (17.4)**	5026 (78.7)***	540 (8.5)***	386 (6.0)**
Spontaneous onset of labour P2	5276	181 (3.4)	882 (16.7)**	4213 (79.9)***	411 (7.8)***	283 (5.4)***
Term birth in Pregnancy 1 and SOP2	5046	133 (2.6)	802 (15.9)*	4111 (81.5)***	391 (7.8)***	249 (4.9)***
Caesarean Section- 1st Stage						
All cases	1790	108 (6.0)**	589 (32.9)***	1093 (61.1)***	216 (12.1)***	189 (10.6)***
Spontaneous onset of labour P2	1036	66 (6.4)***	184 (17.8)	786 (75.9)	133 (12.8)***	100 (9.7)***
Term birth in Pregnancy 1 and SOP2	963	52 (5.4)***	156 (16.2)	755 (78.4)	115 (11.9)***	85 (8.8)***
Caesarean Section- 2nd Stage						
All cases	456	46 (10.1)***	179 (39.3)***	231 (50.7)***	55 (12.1)***	61 (13.4)***
Spontaneous onset of labour P2	246	31 (12.6)***	62 (25.2)*	153 (62.2)***	34 (13.8)***	36 (14.6)***
Term birth in Pregnancy 1 and SOP2	232	24 (10.3)***	59 (25.4)**	149 (64.2)***	30 (12.9)***	32 (13.8)***

Data are expressed as n (%). Cases compared with the corresponding group of women with normal vaginal birth by Chi-square with Yates correction.
*p<0.05, **p<0.005, ***p<0.0005 a = p<0.0001 Chi-square with Yates correction

Term birth: labour ≥37 weeks, P2: second pregnancy, SOP2: spontaneous onset of labour in pregnancy 2

Preterm birth:
1st stage CS vs SVD RR 1.34, 95% CI 1.11 to 1.63, p<0.005,
2nd stage CS vs SVD RR 2.1041 95% CI 1.5877 to 2.7884 P < 0.0001
1st stage CS vs Instrumental delivery RR 1.57, 95% CI 1.26 to 1.95 P < 0.0001
2nd stage CS vs Instrumental delivery RR 2.46, 95% CI 1.82 to 3.32 P < 0.0001

All cases neonatal unit admission in the second pregnancy 12.5% following CS in the first pregnancy, cf 5.3% in women with vaginal birth (RR 2.1, 95% CI 1.86 to 2.40 p<0.0001). NNT 17.063 95% CI 20.55 to 14.59

Supplementary Table 1
Correlation of maternal and pregnancy characteristics with duration of pregnancy 1.

Participants' characteristics	Spearman's Rho	Days of gestation in pregnancy 1
Days of gestation in pregnancy 1	Correlation Coefficient	1.000
	Sig. (2-tailed)	.
	N	30838
Maternal age at booking	Correlation Coefficient	0.040**
	Sig. (2-tailed)	<0.001
	N	30835
Maternal height at booking	Correlation Coefficient	0.088**
	Sig. (2-tailed)	<0.001
	N	30838
Maternal weight at booking	Correlation Coefficient	0.100**
	Sig. (2-tailed)	<0.001
	N	30336
Maternal Race		
White European	Correlation Coefficient	0.125**
	Sig. (2-tailed)	<0.001
	N	30838
Black African	Correlation Coefficient	-0.016**
	Sig. (2-tailed)	-0.016**
	N	30838
Black Caribbean	Correlation Coefficient	-0.023**
	Sig. (2-tailed)	<0.001
	N	30838
South Asian	Correlation Coefficient	-0.123**
	Sig. (2-tailed)	<0.001
	N	30838
East Asian	Correlation Coefficient	-0.015*
	Sig. (2-tailed)	0.010
	N	30838
Mediterranean	Correlation Coefficient	-0.007
	Sig. (2-tailed)	0.237
	N	30838
Single unsupported mother	Correlation Coefficient	--.016**
	Sig. (2-tailed)	0.005
	N	30836
Smoking in pregnancy 1	Correlation Coefficient	-0.018**
	Sig. (2-tailed)	0.002
	N	30819
Diabetes in pregnancy 1	Correlation Coefficient	-0.033**
	Sig. (2-tailed)	<0.001
	N	30802
Oxytocin augmentation in pregnancy 1	Correlation Coefficient	0.098**
	Sig. (2-tailed)	<0.001
	N	30810
History of cardiac disease	Correlation Coefficient	0.006
	Sig. (2-tailed)	0.287
	N	30792
Hypertension at any time	Correlation Coefficient	-0.011
	Sig. (2-tailed)	0.064
	N	30835
Urinary tract infection	Correlation Coefficient	<0.001
	Sig. (2-tailed)	0.991
	N	30793
Epidural use in pregnancy 1	Correlation Coefficient	0.076**
	Sig. (2-tailed)	<0.001
	N	30838

Supplementary Table 2
Factors correlating with the difference in gestational length between pregnancy 1 (P1) and pregnancy 2 (P2)

Participants' characteristics	Spearman's Rho	Difference in gestational length between P1 and P2
Mothers age at booking	Correlation Coefficient Sig. (2-tailed) N	0-.012* 0.035 30835
Mothers height at booking	Correlation Coefficient Sig. (2-tailed) N	0.003 0.547 30838
Mothers weight at booking	Correlation Coefficient Sig. (2-tailed) N	0.013* 0.020 30336
Maternal Race		
White European	Correlation Coefficient Sig. (2-tailed) N	.003 0.642 30838
Black African	Correlation Coefficient Sig. (2-tailed) N	-0.001 0.922 30838
Black Caribbean	Correlation Coefficient Sig. (2-tailed) N	-0.002 0.712 30838
South Asian	Correlation Coefficient Sig. (2-tailed) N	0.002 0.763 30838
East Asian	Correlation Coefficient Sig. (2-tailed) N	0-.012* 0.042 30838
Mediterranean	Correlation Coefficient Sig. (2-tailed) N	-0.005 0.350 30838
Single unsupported mother	Correlation Coefficient Sig. (2-tailed) N	0.002 0.739 30836
Smoking in pregnancy	Correlation Coefficient Sig. (2-tailed) N	-0.008 0.179 30819
Diabetes in pregnancy	Correlation Coefficient Sig. (2-tailed) N	0.006 .322 30802
Oxytocin augmentation in pregnancy 1	Correlation Coefficient Sig. (2-tailed) N	-0.037** <0.001 30810
History of cardiac disease	Correlation Coefficient Sig. (2-tailed) N	-0.007 0.244 30792
Hypertension at any time	Correlation Coefficient Sig. (2-tailed) N	0.001 0.831 30835
Urinary tract infection	Correlation Coefficient Sig. (2-tailed) N	-0.004 0.513 30793
Epidural use in the first stage pregnancy 1	Correlation Coefficient Sig. (2-tailed) N	-0.041** <0.001 30838

Supplementary Table 3

Correlation of the duration of the first and second stages of labour with the difference between the length of the first and second pregnancies, controlling for mode of delivery, oxytocin administration and use of epidural anaesthesia

Model	Unstandardized B	Coefficients Std. Error	Standardised Coefficients BetA	t	Sig.
(Constant)	2.329	.189		12.322	<0.001
Instrumental vaginal birth in pregnancy 1	-.414	.223	-.012	-1.857	0.063
Caesarean section in the first stage in pregnancy 1	-4.604	.374	-.076	-12.325	<0.001
Caesarean section in the second stage in pregnancy 1	-7.485	.685	-.064	-10.930	<0.001
Epidural use in the first stage of pregnancy 1	.430	.204	.014	2.104	0.035
Oxytocin augmentation in pregnancy 1	-.457	.180	-.016	-2.533	0.011
Length of first stage of labour (hr) pregnancy 1	-.164	.018	-.056	-9.130	<0.001
Length of second stage of labour (hr) pregnancy 1	-.559	.089	-.041	-6.261	<0.001

Coefficients[a]
a. Dependent Variable: Difference in gestational length between pregnancy 1 and pregnancy 2

Spontaneous vaginal birth was excluded as a variable because of collinearity

Supplementary Table 4

Relationship of the length of the first and second stages of labour with the difference between the length of the first and second pregnancies.

Stage of Labour	Group	Constant	Unstandardised Beta	P
First Stage	Normal birth	1.326	-0.120	<0.001
	Instrumental birth	1.441	-0.219	<0.001
	CS first stage	-0.076	-0.359	<0.001
	CS second stage	-5.966	-0.223	0.116
Second Stage	Normal birth	1.235	-0.955	<0.001
	Instrumental birth	-0.609	-0.015	0.243
	CS second stage	-7.679	-0.047	0.317