DR SOHINEE BHATTACHARYA (Orcid ID : 0000-0002-2358-5860)

DR MAIREAD BLACK (Orcid ID : 0000-0002-6841-8601)

Intervention thresholds and cesarean section rates: a time-trends analysis

Running title: Clinician thresholds and cesarean section

Anna ROSE[1], Edwin Amalraj RAJA[2], Sohinee BHATTACHARYA[3] & Mairead BLACK[4]

[1]NHS Greater Glasgow and Clyde, Glasgow, [2]Department of Medical Statistics, University of Aberdeen, Aberdeen, [3]Obstetric Epidemiology, University of Aberdeen, Aberdeen,

[4]Obstetrics, University of Aberdeen, Aberdeen, UK

Corresponding author:

Mairead Black
University Department of Obstetrics and Gynecology, Aberdeen Maternity Hospital, Cornhill Road, AB25 2ZD Aberdeen, UK

email: mairead.black@abdn.ac.uk

Conflicts of interest

The authors have no conflicts of interest to declare.

Abstract

Introduction: In order to improve understanding of rising cesarean section (CS) rates in the UK, this study assessed the relation between clinician thresholds for performing CS for delayed labor progress or suspected fetal distress and corresponding CS rates in Aberdeen, UK.

Material and methods*:* Time-trends analysis of term births from 1988 to 2012 in a population of nulliparous women (n=53 745) in Aberdeen, UK using Chi-square test for trend, and binary logistic regression. Data was obtained from the Aberdeen Maternity and Neonatal Databank.

Results: Unplanned CS rates per quintile increased from 11.0% (1391/12 686) to 21.1% (2383/11 273) between 1988 and 2012, while planned CS rates increased from 2.7% (338/12 686) to 5.2% (591/11 273). The median duration of labor before CS for delayed progress per quintile decreased from 17.2 (IQR 12.5 to 22.3) hours to 13.1 (9.6 to 16.9) hours before first stage CS and from 17.1 (12.6 to 22.3) to 15.3 (11.5 to 19.1) hours before second stage CS, $p<0.001$. The proportion of CS for suspected fetal distress performed with evidence of fetal acidosis reduced from 23.4% (98/418) to 17.4% (106/608) per quintile, $p<0.01$. Neonatal unit admission (adj. OR 1.99, 95% CI 1.85–2.14) was more likely following unplanned CS compared with vaginal births. Birth trauma was less likely following both unplanned (OR 0.48, 95% CI 0.39–0.60) and planned (OR 0.33, 95% CI 0.18–0.63)} CS.

Conclusion: Increased CS rates can be partly attributed to lowered clinical thresholds for intrapartum CS. Higher CS rates are associated with less birth trauma for the offspring.

Keywords

cesarean, intrapartum, clinical threshold

Abbreviations

CS – cesarean section

BMI – body mass index

IOL – induction of labor

FBS – fetal blood sample

Key message Lowered clinical thresholds for intrapartum cesarean section partly explain rising cesarean section rates and are associated with reduced birth trauma in Aberdeen, UK.

Introduction

Cesarean section (CS) accounted for 32% of births in Scotland in 2016, a three-fold increase since 1976 (1). Over a quarter of first births involve unplanned CS and one in seven of all births are planned CS (1,2). While improved maternal and neonatal survival are associated with overall CS rates of 19% globally, no improvement is seen beyond this rate (3-6). Addressing apparent over-use of CS requires understanding of why CS rates are high.

Medical, social, and legal factors are known to shape CS decisions (4,7). Fear of legal repercussions from an adverse outcome of a plan for vaginal birth places increasing pressure on clinicians to offer CS birth, potentially in response to relatively minor pregnancy or labor complications (8). This issue has been exacerbated substantially in the UK by a 2015 Supreme Court ruling on informed consent in healthcare which means that all women aiming for vaginal birth should be counselled on the comparative advantages and disadvantages of CS as an alternative (9,10). Increased maternal age and body mass index (BMI) appear to raise CS risk before and during labor, while a breech presentation or a previous CS are accepted medical indications for pre-labor CS, but further explanations for rising CS rates are sought (11-13).

Lowered clinician thresholds for performing CS for subjective diagnoses may be key to further understanding of high and variable CS rates. This applies to the leading indications for primary CS: delayed progress in labor and suspected fetal distress (14). Minimal data exists to support or refute that thresholds have changed (10,15-17). Lowered thresholds for diagnosing delayed labor progress may be indicated by a shortened average duration of labor before performing CS. In the context of suspected intrapartum fetal distress, a lowered diagnostic threshold may be indicated by a reduced proportion of these CS having confirmed fetal acidosis (18-20). Assessment of such thresholds for performing unplanned CS have not been thoroughly investigated, nor has the effect of CS on neonatal outcome (5). These issues are addressed in this work.

This study aimed to assess the degree to which demographic and clinical factors, including clinical thresholds for performing a CS, explain changes in planned and unplanned CS rates over time, and to explore the relation between these deliveries and neonatal outcomes.

Material and methods

A time-trends analysis of deliveries in Aberdeen City and District between 1988 and 2012 was performed. All data was obtained from the Aberdeen Maternity and Neonatal Databank, a computerized database containing validated data on all pregnancy-related events at Aberdeen Maternity Hospital, UK, since 1949

(http://www.abdn.ac.uk/iahs/research/obsgynae/amnd/index.php). Coding in this database follows that of the International Classification of diseases, 9th and 10th revisions. Data is entered by dedicated trained staff with regular consistency checks performed. Researchers received anonymized data from the data-holding team. Data cleaning involved identification of cases with missing variables and checking of any implausible values with the data-holding team.

A total of 53 745 primiparous women who delivered at term between 1988 and 2012 were included as shown in figure 1. This study period featured contemporary labor practices in a stable population. Because mode of delivery in a first pregnancy strongly determines overall CS rates, and decisions on when to diagnose delayed progress in labor vary according to parity (21,20), the study population was limited to primiparous women delivering term infants (greater than or equal to 37 completed weeks gestation).

Unplanned and planned CS rates (%) by year quintiles from 1988 to 2012 were measured. Change in unplanned CS rates per year were calculated, adjusting for maternal age, BMI, induction of labor (IOL) rate, clinician threshold for performing CS due to lack of labor progress and clinician threshold for CS due to suspected fetal distress. Change in planned CS rate per year was adjusted for maternal age and BMI. The original protocol stated that all CS rates would be measured per year rather than per year quintile. The decision to calculate using year quintiles was made following visual inspection of the data distribution which required smoothing.

Gestational age was recorded at delivery in completed weeks, based on last menstrual period confirmed by ultrasound examination. Maternal age was recorded in completed years at delivery; maternal BMI was calculated at booking appointment using the equation BMI (kgm^{-2})=weight(kg)/height^2(m). For multiple pregnancies, only mode of birth for the first baby was assessed. Each woman who had a CS was assigned a primary indication for CS, from a possible list of nine reasons, using the 'Causal Model for Indications of CS' or 'Ontario Classification' as used by Lomas et al. (22). This method prioritized 'failure to progress in labor' over 'suspected fetal distress'. Rates of overall, planned and unplanned CS were calculated as a percentage of all primary, term deliveries for each year (1988-2012). An 'abnormal' fetal blood sample (FBS) was defined as pH less than or equal to 7.20. Neonatal death was defined as death within the first 28 days of life; a 'low' Apgar was defined as a score of less than seven at five minutes. A diagnosis of 'birth trauma' included injury to the scalp (cephalohaematoma significant enough to require neonatalogy input), cranium, skeleton or nervous system (central or peripheral). For the purposes of facilitating comparisons with other studies the Robson Ten Group Classification System (23) was applied to all women in the study.

In order to calculate clinical thresholds for the two leading CS indications in each time period, only cases with a recorded indication for CS were assessed. The median duration of labor (hours) in first and, where relevant, in second stage of labor before unplanned CS for delayed progress was calculated per quintile, and the percentage of unplanned CS performed for suspected fetal distress with an abnormal FBS result was calculated per quintile. These values were assigned to each woman according to when she delivered, reflecting the threshold for CS to which she was exposed.

All cases were included in analyses of predictors of planned and unplanned CS birth. Due to lack of data in earlier years, analyses of neonatal unit admissions were restricted to 1992 onwards and those of birth trauma to 1996 onwards. For all analyses, complete case analysis was performed.

Rates of overall, planned and unplanned CS were calculated as a percentage of all primary, term deliveries for each five year period between 1988 and 2012. Mean (SD) or median (IQR) were calculated for the continuous maternal characteristics depending upon data distribution.

The first analysis stage involved assessment of time trends in each of: CS rates; potential predictors of CS rates; and offspring outcomes associated with CS birth, using Chi-square test for trend and ANOVA for binary and continuous variables respectively.

In the second analysis stage, multivariate binary logistic regression was used to find the association between types of CS (planned and unplanned CS) and year of delivery (risk of CS per year), after adjusting for potential predictors of CS risk including; maternal age (years); maternal BMI (kgm^{-2}); smoking status (smoker vs. non-smoker); IOL (induced vs. spontaneous labor); gestation (week); and indicators of thresholds for CS (due to delayed progress in labor and suspected fetal distress in the index year of delivery) specific to the unplanned CS analysis only. Odds ratio and its 95% confidence interval were reported. The odds of planned CS was compared to all other deliveries, while the odds of unplanned CS was assessed within a population who did not have a planned CS.

In the third analysis stage, the association between planned and unplanned CS and adverse neonatal outcomes was assessed using binary logistic regression models including potential confounders and year of delivery, with the dependent variable being the neonatal outcome of interest. Outcomes studied included neonatal death, low Apgar score at five minutes (less than seven), admission to the neonatal unit and incidence of birth trauma. Multivariable binary logistic regression was used to calculate these risks with 95% confidence intervals. Statistical significance was reported at the 5% level and all statistical analyses were conducted using IBM SPSS STATISTICS, version 22 (IBM, Armonk, NY, USA).

Results

Data completeness ranged from 91.6% for smoking data to 100% for gestation at delivery and IOL data, as shown in Table 1. Fifteen cases were excluded from the analysis as mode of delivery was not known.

From 1988 to 2012, there were 53 760 deliveries at term to nulliparous women. The CS rate increased from 13.62% to 26.37% of all primary, term deliveries across the study period, as shown in Figure 2. This trend was statistically significant. The planned CS rate increased from 2.66% to 5.24% and the unplanned CS rate from 11.0% to 21.14% over the study period, with divergence in the final quintile as planned CS increased and unplanned CS decreased, as shown in Table 1. Between 1988 and 2012, 97.8% of the 9876 unplanned CS had an indication for CS recorded. Of these, 87.5% (n=8455) were performed for either failure to progress in labor (n=5901, 61.1%) or suspected fetal distress (n=2554, 26.4%). As a percentage of all primary, term deliveries, unplanned CS performed for delayed progress in labor, and those performed for suspected fetal distress in labor, increased from 5.71% to 12.52% and from 3.29% to 5.39% respectively. A significant increase in both the median maternal age (from 25 to 28 years) and mean BMI (from 24.2 to 25.4kgm^{-2}) was demonstrated over the study period, with a plateau observed across the final two quintiles for each. The IOL rate, as a percentage of all primary, term deliveries, also increased from 25.9% to 33.6%; while the proportion of mothers who smoked decreased from 30.0% to 15.2%, *p*<0.001 (Figure 3 and Table 1).

Table 2 demonstrates the classification of women undergoing CS in the cohort using the Robson Ten Group Classification System (24). Of all primary term CS, 32.9% fell into group 1 (nulliparous, single, cephalic, ≥37 completed weeks gestation, spontaneous labor) and 46.9% were group 2 (nulliparous, single, cephalic, ≥37 completed weeks gestation, induced or CS before labor).

The adjusted odds of CS (planned or unplanned) for a first-time mother delivering at term increased by an annual percentage increase of 3% between 1988 and 2012, incorporating a plateau between 2003 and 2012. As maternal age increased by one year, the adjusted odds of planned CS increased by 9% and risk of unplanned CS increased by 7%. Maternal smoking was not significantly associated with odds of planned or unplanned CS in adjusted analyses. As the number of completed weeks gestation increased by one week, the odds of planned CS were approximately halved, while the odds

of unplanned CS increased by 12%. Each unit increase in maternal BMI was associated with an 8% increased risk of planned CS and a 6% increase in odds of unplanned CS. IOL was associated with a doubling of odds of unplanned CS (Table 3).

From 1988 to 2012, the median (25th and 75th percentile) duration of time a woman spent in labor before having an unplanned CS for delayed progress (per year) decreased from 17.7 hours (12.8,23.2) to 14.2 (10.8,16.9) hours in the first stage and 18.4 (11.9,21.5) to 15.3 (12.4,18.2) hours in the second stage. As shown in Table 4, for each hour increase in average labor duration before a CS for delay in labor, the odds of unplanned CS fell by 15% during the first stage and 10% in second stage. The inverse of this indicates that as thresholds fell over time (duration of labor before CS for delayed labor progress reduced), the risk of CS increased.

The percentage of unplanned CS performed for suspected fetal distress with an abnormal FBS result (pH less than or equal to 7.20) decreased from 23.4% in the first quintile to 17.4% in the fifth. Odds of unplanned CS fell by 2% as thresholds for performing CS for suspected fetal distress rose by one percentage point in terms of proportion of such CS performed following confirmed fetal distress. The inverse of this relationship therefore indicated that, as thresholds fell over time, the risk of CS increased (Table 4).

Overall, neonatal outcomes in the whole cohort improved since 1988 with an annual decrease in neonatal deaths, deliveries with a low Apgar score and birth trauma between 1988 and 2012 of 3%, 3% and 2% respectively. However, there was a slight annual increase in the odds of neonatal unit (NNU) admissions. Babies delivered at term by planned CS are more likely to die within the first 28 days of life compared to all other modes of delivery, even after adjustment for time, maternal age, BMI and gestation, as demonstrated in Table 5. Delivery by planned CS was associated with reduced risk of a low Apgar score at five minutes. The adjusted risk of low Apgar for babies delivered by unplanned CS is more than double that of babies delivered vaginally.

Data from 1992-2012 demonstrates that babies born by unplanned CS are twice as likely to be admitted to the NNU, compared to those delivered vaginally. CS delivery appears to protect against birth trauma especially unplanned CS where the odds is more than halved compared to all other modes of delivery except planned CS (Table 5).

Discussion

This single-center population-based study has shown that, in addition to changes in maternal demographic factors, lowering of clinical thresholds for performing CS in labor partly explain rising CS rates. This is the first study to our knowledge that has assessed the thresholds for performing CS due to suspected fetal distress. Indicators of clinical thresholds to perform unplanned CS suggest that these have fallen over time. Decisions are made to perform CS for delayed progress after shorter durations of labor, while CS for suspected fetal distress are more often performed in the absence of evidence of fetal acidosis. The study demonstrated that planned and unplanned CS are more likely with increased maternal age and BMI, while unplanned CS is also associated with IOL.

Despite a more than doubling of both planned and unplanned CS since 1988, of all adverse neonatal outcomes assessed, only birth trauma is less likely following both CS types, while low Apgar score is less likely with planned CS. Over time, less CS are performed in women laboring spontaneously at term and more are conducted in those where labor was induced or CS was planned.

The time trends in CS rates in Aberdeen are in keeping with those reported elsewhere in Scotland and the UK (1,24-26). Maternal age and BMI are known predictors of CS risk in such populations, suggesting that pregnancy and labor mechanisms are affected by these factors (11,13,14,24,26,27). The increased planned CS rate over time may reflect greater antenatal morbidity and increased awareness of women at high risk of unplanned CS in labor. The higher likelihood of CS following induced labor is understood not to be causal, as randomized controlled trials of IOL have demonstrated (28,29). The positive association is highly likely to reflect the underlying indication for IOL, with hypertensive disorders and fetal growth restriction being major potential confounders.

The contribution of intrapartum CS for subjective indications (delay in labor progress and suspected fetal distress) to overall CS rates is in keeping with a US study by Barber et al. (10), which found that 50% of the increase in primary CS was explained by procedures for these indications. Our data suggesting falling clinician thresholds for performing CS due to delayed progress in the first stage of labor appears to be novel, and recent published data on the second stage of labor agrees with our findings that overall duration before CS has increased (30). Previous authors have speculated that clinical thresholds had fallen in order to explain increased intrapartum CS rates in first-time mothers (16,17) but limited data prevented exploration of this. Increasing evidence that FBS is of limited value may partly explain the reduction in confirmation of fetal acidosis before performing CS for suspected fetal distress.

The higher risk of neonatal deaths following planned CS reflects complex pregnancies and is consistent with previous findings from a WHO study (4). Our data on indication for CS for affected cases (not presented due to risk of disclosure in relation to small numbers) supports that these findings can be explained by known fetal pathology. Increased NNU admission may be due to increased respiratory morbidity, a recognized risk of CS. Our findings of no change in overall neonatal mortality rates over time, despite the rise in planned and unplanned CS rates, suggest that high CS rates are not saving neonatal lives. The association between planned CS and reduced risk of birth trauma is expected as the hazards of vaginal birth are avoided.

This study benefits from a validated source of routinely-collected population data. The level of detail held in the Aberdeen Maternity and Neonatal Databank on duration and stage of labor exceeds that of maternity data sources globally, providing a unique opportunity to explore the role of clinician thresholds in determining CS rates. By adjusting all models for year of delivery, the role of practice changes over time could be adjusted for. As the study represents practice in a UK tertiary referral center, it is expected to be generalizable to other tertiary centers in similar high-income settings, particularly where services are government funded. Study limitations include lack of data on clinical features such as pyrexia in labor which may have contributed to a decision for intrapartum CS. However, no such potential factors are recognized to have changed over time beyond those adjusted for in this study. A further important limitation is the lack of data on maternal outcomes over time. Clearly the impact of lowered clinical thresholds for performing CS in labor have potential implications, possibly positive and negative, for mother, baby and future pregnancies. These include potential psychological benefits from avoiding emergency events in labor and physical benefits from

reducing risk of pelvic floor disorders, but risks include reduced fertility, morbidly adherent placenta and, in extreme cases, CS scar rupture. All must be considered before recommendations on future practice can be made.

In conclusion, increased CS rates can be partly attributed to maternal characteristics and clinical thresholds for intrapartum CS. Indication for CS likely explains why adverse neonatal outcomes were more common following planned and unplanned CS compared with vaginal birth, but CS appears protective against neonatal birth trauma. Future work to improve understanding of clinical thresholds for performing CS should include qualitative and quantitative exploration of factors contributing to a diagnosis of delayed progress in labor or sufficient suspicion of fetal distress. Recognizing that a reduction in birth trauma and low Apgar score follows planned CS is important and should be considered when weighing up risks and benefits of planned CS birth.

Funding

REFERENCES:

(1) Information Services Division. Births in Scottish Hospitals. 2014. Available from: https://files.digital.nhs.uk/publicationimport/pub16xxx/pub16725/nhs-mate-eng-2013-14-tab-v1.xlsx (accessed 22 May 2018)

(2) Hospital Episode Statistics Analysis. Hospital Episode Statistics, NHS Maternity Statistics – 2014. Available from https://digital.nhs.uk/data-and-information/publications/statistical/nhs-maternity-statistics/2013-14 (accessed 22 May 2018)

(3) Betran AP, Torloni MR, Zhang JJ, Gülmezoglu AM for the WHO Working Group on Caesarean Section. WHO Statement on Caesarean Section Rates. BJOG 2016;123;667-670.

(4) Villar J, Valladares E, Wojdyla D, Zavaleta N, Carroli G, Velazco A. Caesarean delivery rates and pregnancy outcomes: the 2005 WHO global survey on maternal and perinatal health in Latin America. Lamcet 2006;367(9525):1819-1829.

(5) Gibbons L, Belizán JM, Lauer JA, Betrán AP, Merialdi M, Althabe F. The Global Numbers and

Costs of Additionally Needed and Unnecessary Caesarean Sections Performed per Year: Overuse as a Barrier to Universal Coverage. 2010;30. Available at: http://www.who.int/healthsystems/topics/financing/healthreport/30C-sectioncosts.pdf (accessed 22 May 2018)

(6) Molina G, Weiser TG, Lipsitz SR et al. Relationship between cesarean delivery rate and maternal and neonatal mortality. JAMA 2015;314(21).

(7) Witt WP, Wisk LE, Cheng ER et al. Determinants of cesarean delivery in the US: a lifecourse approach. Matern Child Health J. 2015;19;84-93.

(8) Yang TY, Mello MM, Subramanian SV, Studdert DM. Relationship between malpractice litigation pressure and rates of cesarean section and vaginal birth after cesarean section. Med Care. 2009;47: 234-42.

(9) Montgomery v Lanarkshire Health Board. [2015] UKSC 11 [2015]. Available at: https://www.supremecourt.uk/decided-cases/docs/UKSC_2013_0136_Judgment.pdf (accessed 22 May 2018)

(10) Barber EL, Lundsberg LS, Belanger K, Pettker CM, Funai EF, Illuzzi JL. Indications contributing to the increasing cesarean delivery rate. Obstet Gynecol. 2011;118(1):29-38.

(11) Poobalan AS, Aucott LS, Gurung T, Smith WCS, Bhattacharya S. Obesity as an independent risk factor for elective and emergency caesarean delivery in nulliparous women – systematic review and meta-analysis of cohort studies. Obes Rev. 2009;10:28-35.

(12) Haerskjold A, Hegaard HK, Kjaergaard H. Emergency caesarean section in low risk nulliparous women. J Obstet Gynaecol. 2012;32(6):543-7.

(13) Centre for Maternal and Child Enquiries (CMACE). Maternal obesity in the UK: Findings from a National Project. London: CMACE, 2010. Available at: http://www.oaa-anaes.ac.uk/assets/_managed/editor/File/CMACE/CMACE_Obesity_Report_2010_Final%20for%20printing.pdf (accessed 22 May 2018)

(14) Timofeev J, Reddy UM, Huang CC, Driggers RW, Landy HJ, Laughon SK. Obstetric complications neonatal morbidity, and indications for cesarean delivery by maternal age. Obstet Gynecol. 2013 Dec;122(6):1184-95.

(15) Robson M, Hartigan L, Murphy M. Methods of achieving and maintaining an appropriate caesarean section rate. Best Pract Res Clin Obstet Gynaecol. 2013;27(2):297-308.

(16) Nippita TA, Lee YY, Patterson JA et al. Variation in hospital caesarean section rates and obstetric outcomes among nulliparae at term: a population-based cohort study. BJOG. 2015;122(5):702-11.

(17) Leitch CR, Walker JJ. The rise in caesarean section rate: the same indications but a lower threshold. BJOG. 1998;105:621-626.

(18) Paranjothy S, Frost C, Thomas J. How much variation in CS rates can be explained by case mix differences? BJOG. 2005;112(5):658-66.

(19) National Institute for Health and Care Excellence. Caesarean Section. 2011. Available at: https://www.nice.org.uk/guidance/cg132# (accessed 22 May 2018)

(20) National Institute for Health and Care Excellence. Intrapartum care for healthy women and babies. 2017. Clinical guideline [CG190] Available at https://www.nice.org.uk/guidance/cg190 (accessed 22 May 2018)

(21) American College of Obstetricians and Gynecologists and Society for Maternal-Fetal Medicine. Safe Prevention of the Primary Cesarean Delivery. 2014. Available at: https://www.acog.org/-/media/Obstetric-Care-Consensus-Series/oc001.pdf?dmc=1&ts=20180528T0319089578 (accessed 22 May 2018)

(22) Anderson GM, Lomas J. Recent trends in cesarean section rates in Ontario. CMAJ 1989;141:1049-1053.

(23) Torloni MR, Betran AP, Souza JP, et al. Classifications for caesarean section: a systematic review. PLoS One. 2011;6(2):e14566.

(24) Bragg F, Cromwell DA. Edozien LC, et al. Variation in rates of caesarean section among English NHS trusts after accounting for maternal and clinical risk: cross sectional study. BMJ. 2010;341:c50665.

(25) Black C, Kaye JA, Jick H. Cesarean delivery in the United Kingdom. Obstet Gynecol. 2005 Jul;106(1):151-5

(26) Smith GCS, Cordeaux Y, White IR, et al. The effect of delaying childbirth on primary cesarean section rates. PloS Med. 2008;5(7):e144

(27) Parliamentary Office of Science and Technology. Caesarean Sections. 2002. Available at: http://researchbriefings.files.parliament.uk/documents/POST-PN-184/POST-PN-184.pdf (accessed 22 May 2018)

(28) Wood S, Cooper S, Ross S. Does induction of labour increase the risk of caesarean section? A systematic review and meta-analysis of trials in women with intact membranes. BJOG. 2014;121(6):674-85; discussion 685.

(29) Mishanina E, Rogozinska E, Thatthi T, Uddin-Khan R, Khan KS, Meads C. Use of labour induction and risk of cesarean delivery: a systematic review and meta-analysis. CMAJ. 2014;186(9):665-73.

(30) Fitzwater JL, Owen J, Ankumah N, Campbell SB, Biggio JR, Szychowski JM. Nulliparous Women in the second stage of labour. Am J Obstet Gynecol. 2015;212(1):141-142.

Figure legends

Figure 1. Study population flow chart.

Figure 2. Changes in cesarean section (CS) rates, overall, planned and unplanned, as a percentage of all primary, term deliveries, from 1988 to 2012 in Aberdeen, UK.

Figure 3. Changes in maternal and clinical characteristics for first-time mothers delivering at term, from 1988 to 2012 in Aberdeen, UK.

Table 1. Time trends in cesarean section deliveries, potential predictors of cesarean delivery and neonatal outcomes in Aberdeen, UK from 1988 to 2012 calculated using chi-squared test for trend and ANOVA.

Population feature		1988-1992	1993-1997	1998-2002	2003-2007	2008-2012	*p*-value[a]
Average CS rate (%)	Overall CS (n/N)	13.62 (1728/12686)	18.02 (1991/11011)	26.81 (2506/9347)	28.35 (2670/9418)	26.37 (2973/11273)	**<0.001**
	Planned CS (n/N)	2.66 (338/12 686)	3.25 (358/11 011)	3.49 (326/9347)	4.06 (382/9418)	5.24 (591/11 273)	**<0.001**
	Unplanned CS (n/N)	10.96 (1391/12 686)	14.83 (1633/11 011)	23.31 (2180/9347)	24.30 (2289/9418)	21.14 (2383/11 273)	**<0.001**
	Missing delivery detail (n)	5	2	4	0	4	
Median Maternal age in years (IQR) Missing (n)		25 (22,28) 6	27 (23,30) 3	27 (23,31) 0	28 (23,32) 3	28 (24,32) 11	**<0.001**
Mean Maternal BMI± SD Missing (n)		24.2 ± 3.9 1227	24.62 ± 4.4 857	24.77 ± 4.7 582	25.19 ± 5.1 572	25.41 ± 5.4 454	**<0.001**
Maternal Smoking rate (%) Missing (n)		30 (3541/11 810) 876	25.10 (2557/10 186) 825	23.64 (1984/8394) 953	19.88 (1674/8422) 996	15.21 (1540/10 126) 1147	**<0.001**
Induction of labor rate (%) Missing (n)		25.87 (3282/12 686) 0	28.58 (3147/11 011) 0	34.92 (3265/9347) 0	34.49 (3248/9418) 0	33.63 (3792/11 273) 0	**<0.001**
Median duration of labor before CS for failed progression in hours (IQR) Missing (n)	*Stage 1 CS*	17.17 (12.47,22.30) 0	15.43 (11.72,19.46) 0	13.43 (10.32,17.00) 0	12.25 (9.15,16.04) 0	13.10 (9.63,16.88) 0	**<0.001**
	Stage 2 CS	17.05 (12.60,22.28) 0	15.67 (12.20,18.95) 0	13.66 (10.42,17.63) 0	13.65 (10.76,17.21) 0	15.25 (11.47,19.07) 0	**<0.001**
Threshold for CS for suspected fetal distress (% confirmed fetal acidosis) n/N Missing (n)[b]		23.44 (98/418) 233	24.52 (116/473) 269	19.48 (97/498) 274	11.67 (65/557) 350	17.43 (106/608) 363	**0.015**
Median estimated gestation at delivery in weeks (IQR) Missing (n)		40 (38,42) 0	40 (38,42) 0	40 (38,42) 0	40 (38,42) 0	40 (38,42) 0	**<0.001**
Apgar score <7 at five minutes (%) Missing (n)		2.09 (264/12648) 38	1.80 (198/10 996) 15	1.38 (129/9333) 14	1.40 (132/9400) 18	1.33 (150/11 250) 23	**<0.001**
Neonatal unit admission rate (%) Missing (n)		–	9.72 (1070/11 011) 0	12.73 (1190/9347) 0	13.84 (1303/9418) 0	10.45 (1178/11 273) 0	**0.023**
Birth trauma rate (%) (% missing)		–	–	2.71 (253/9347) 0	2.60 (245/9418) 0	2.03 (229/11 273) 0	**0.001**

| Neonatal death rate (%) | 0.17 (22/12 686) | 0.22 (24/11011) | 0.08 (7/9347) | 0.21 (20/9418) | 0.07 (8/11 273) | 0.055 |
| Missing (0) | 0 | 0 | 0 | 0 | 0 | |

a chi-squared test for trend. Empty cells reflect data unavailable for that period.

b Those cases in which no fetal blood sample was performed or result recorded.

Bold indicates significant results. IQR, interquartile range; BMI, body mass index; SD, standard deviation.

Table 2. Breakdown of all primary, term cesarean section (CS) in Aberdeen, UK, 1988-2012 according to the Robson Ten Group Classification System(24) for cesarean section.

Group number	Description	Number of primary, term CS (%)		
		1988 N=328 n (%)	2012 N=645 n (%)	Overall N=11,868 n (%)
1	Nulliparous, single, cephalic, ≥37 completed weeks gestation, spontaneous labor	120 (36.6)	144 (22.3)	3,910 (32.9)
2	Nulliparous, single, cephalic, ≥37 completed weeks gestation, induced or CS before labor	121 (36.9)	381 (59.1)	5,562 (46.9)
6	All nulliparous breeches (including spontaneous labor, induced and CS before labor)	73 (22.3)	98 (15.2)	2,031 (17.1)
8	All multiple pregnancies	3 (0.9)	13 (2.0)	209 (1.8)
9	All abnormal lies (excluding breech)	7 (2.1)	6 (13.3)	156 (1.3)

Table 3. Risk of cesarean section (CS) associated with maternal and clinical characteristics in Aberdeen, UK; 1988-2012.

Potential Predictive Variable	Planned CS				Unplanned CS			
	Unadjusted OR	95% CI	Adjusted OR[g]	95% CI	Unadjusted OR	95% CI	Adjusted OR[h]	95% CI
Year of delivery[a]	1.04	1.03,1.04	1.03	1.02,1.03	1.04	1.04,1.05	1.03	1.02,1.03
Maternal age[b]	1.09	1.08,1.10	1.09	1.08,1.10	1.08	1.08,1.09	1.07	1.07,1.08
Maternal BMI[c](kg/m^2)	1.02	1.01,1.03	1.02	1.01,1.03	1.08	1.08,1.09	1.06	1.06,1.07
Smoker[d]	0.78	0.69,0.88	1.04	0.92,1.18	1.37	1.30,1.45	1.02	0.97,1.10
Induced[e]	-		-		2.58	2.47,2.70	2.17	2.06,2.29
Gestation (weeks)[f]	0.52	0.50,0.54	0.52	0.50,0.54	1.18	1.16,1.20	1.12	1.09,1.14

OR, odds ratio; CI, confidence interval.

[a]Indicates change in odds per increase of one year.

[b]Indicates change in odds per additional year of age.

[c]Indicates change in odds per unit increase in body mass index (BMI).

[d]Indicates change in odds if smoker vs non-smoker.

[e]Indicates change in odds if induced labor vs spontaneous onset.

[f]Indicates change in odds per additional week of gestational age.

[g]indicates odds ratio adjusted for year of delivery, maternal age, BMI, smoking status and gestation; with 95% Confidence Intervals

[h]OR adjusted for year of delivery, maternal age, maternal BMI smoking status, induction of labor and gestation; with 95% Confidence Intervals using complete case analysis {53727 (99.9%) of cases had data on maternal age; 50058 (93.1%) on BMI, 48938 (91.2%) on smoking status, 53750 (100%) on induction of labor and 53750 (100%) on gestation}

Table 4. Risk of unplanned cesarean section (CS) for first-time mothers delivering at term for each hour increase in annual average labor duration before CS for delayed labor progress (indicator of changes in clinical thresholds, 1988-2012) in Aberdeen, UK 1988-2012.

Indicator of Clinical Threshold		Risk of Unplanned CS			
		Unadjusted OR	95% CI	Adjusted[a] OR	95% CI
Median duration of labor before CS for delayed progress in labor[b] (hours)	*Stage 1*	0.84	0.83,0.85	0.85	0.83,0.87
	Stage 2	0.86	0.85,0.87	0.90	0.89,0.92
Deliveries for suspected fetal distress with abnormal fetal blood sample result[c] (%)		0.96	0.95,1.0	0.98	0.97,0.99

OR, odds ratio; CI, confidence interval.

[a]Odds ratio adjusted for time (year of delivery), maternal age, BMI, smoking status, induction of labor, gestation and indicators of clinical thresholds for unplanned CS in labor.

[b]Median duration of labor for all unplanned CS for failure to progress in labor with a recorded duration in the year of delivery.

[c]Percentage of all primary, term deliveries by unplanned CS for suspected fetal distress with an abnormal fetal blood sample result (pH ≤7.20).

Table 5. Risk of adverse neonatal outcome by type of cesarean section (CS) birth for all primary, term deliveries in Aberdeen UK, 1988-2012.

Adverse Neonatal Outcome	Years available	No. deliveries (missing)	Planned CS[a]				Unplanned CS[b]			
			Unadj OR	95% CI	Adj[c] OR	95% CI	Unadj OR	95% CI	Adj[c] OR	95% CI
Neonatal Death	1988-2012	53 750 (0)	**4.98**	2.75, 9.04	**5.67**	2.89,11.11	1.46	0.88,2.42	1.52	0.85,2.73
Low Apgar (<7)	1988-2012	53 750 (113)	0.67	0.44,1.02	**0.61**	0.39,0.96	**1.96**	1.69,2.27	**2.03**	1.73,2.39
Neonatal Unit Admission	1992-2012	43 538 (6)	**1.54**	1.34,1.75	**1.24**	1.08,1.43	**1.99**	1.86,2.13	**1.99**	1.85,2.14
Birth Trauma	1996-2012	34 123 (0)	**0.30**	0.17,0.55	**0.33**	0.18,0.63	**0.54**	0.44,0.66	**0.47**	0.38,0.58

OR, odds ratio; Adj OR, adjusted odds ratio; Unadj OR, unadjusted odds ratio; CI, confidence interval

[a]Compared to unplanned CS and vaginal births combined.

[b]Compared to vaginal births.

[c]Adjusted for time (year of delivery), maternal age, maternal BMI and gestation.

Bold indicates significant results.

Changes in Primary, Term CS rates (1988-2012)

Changes in Maternal Characteristics and Induction of Labour for Nulliparous women (1988-2012)