**Long-term changes in cesarean delivery and recurrence in Norwegian nulliparous women, 1967-2014: A population-based study**

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**Objective**: To describe long-term changes in Cesarean Delivery (CD) and estimate CD recurrence risk across five decades.

**Design**: Population-based cohort study

**Setting**: Norway, 1967-2014

**Sample**: A total of 951,895 nulliparous women with their singleton, cephalic, term deliveries were followed through their first and second births.

**Methods:** Data from the Medical Birth Registry of Norway was used to describe CD by maternal age (years): <20 (reference), 20-24, 25-29, 30-34, 35-39 and >=40 and onset of labor: spontaneous (reference), induced and pre-labor CD. Based on seven risk factors, women were grouped as lower (no factors) - and higher-risk (one or more factors). Risk estimates were stratified by periods: 1967-1982, 1983-1998 and 1999-2014. Multivariable regression models were used to estimate relative risk (RR) with 95% confidence interval (CI).

**Results:** CD in the first birth increased across periods from 3.3% to 10.2% and from 8% to 20.5% in lower- and higher-risk women, respectively. The increase in CD was only found among women < 35 years. Compared to women with spontaneous onset, the RR of CD in lower-risk women with induced onset of labor increased from 3.8 (95% CI 3.6-4.0) to 5.9 (95% CI 5.7-6.2) across periods. Overall CD recurrence risk was 57.9%, but relative recurrence risk was lower in the last than in the first period.

**Conclusion:** Overall CD risk increased over time in Norwegian women <35 years both in lower- and higher- risk groups, while it was stable or decreased in older women. CD recurrence risk declined across 47 years in Norway.

**Key words**: Cesarean delivery, recurrence, population-based study, Robson groups, Norway

**Tweetable Abstract:** Cesarean delivery increased across five decades in Norwegian women <35 years, while recurrence risk declined.

Introduction

Cesarean delivery (CD) has increased in all developed countries(1), with Nordic countries having the lowest rates. Recently there has been a moderate increase in CD also in the Nordic countries(2). Between 2000 to 2011, CD increased by 26%, 15% and 10% in Denmark Norway and Sweden, respectively. In the US, the increase in primary CD and the development in obstetric care, have also contributed to increased recurrence of CD(3). Despite trial of labor after CD being safe for most women, most developed countries have high CD recurrence(3, 4). Finally, higher CD rates are likely to increase adverse complications in the mother and her baby(5, 6) and have economic costs(7).

With the ongoing sociodemographic changes, monitoring CD rates are crucial to identify groups with too high CD rates and contributing factors(8). Nulliparous women and women with previous CD are the two groups contributing strongly to increasing CD in the Nordic countries (2). Risk factors for CD are advanced maternal age(9-12), change in clinical practice and population risk profile such as high body mass index (BMI) (13, 14), but also women’s preferences are important(15). Advanced maternal age is associated with increased risk of bleeding and malpresentation(10), pregnancy complications(16) and obstructed labor (17, 18). Both Smith et.al(17) and Main et al.(18) reported biological changes to the uterine contractility with increasing maternal age. However, a prior study among low risk nulliparous women in Norway and Sweden reported declining CD rates in women older than 35 years (19). This study only focused on women older than 30 years and thus excluded most nulliparous women, as well as not examining women with different risk profiles.

Other factors influencing CD rates include changes induction policy and pre-labor CD(2) and recommendations (20). The link between CD and induction has been much debated, with many studies reporting conflicting findings. Some observational studies found induction of labor in lower-risk nulliparous women to increase risk of CD(4, 21, 22) while others have reported unchanged or lower risk of CD(23-26). In Norway, induction rates have increased from 12.5% in 2003 to 20.3% in 2013, with one in ten inductions performed without any medical indication(23).

To address heterogeneity in risk of CD, the Robson classification has been used as a framework for comparing CD rates between groups with similar, clinically relevant risk factors for CD(27). Two of the Robson groups include nulliparous women with a singleton, term cephalic pregnancy, which make up the vast majority of nulliparous reproductive women(28). The aim of our study was to describe changes in CD rates among these women and sociodemographic factors in Norway across three time periods, covering almost 50 years and to estimate CD recurrence risk.

Methods

**Study Design**

In this population-based cohort study we analyzed data from the Medical Birth Registry of Norway (MBRN) between 1967-2014. The MBRN is based on mandatory notification of all live- and stillbirths from 16 weeks of gestation (12 weeks from 2002) since 1967(29) and prospectively collects data on mother’s health before and during pregnancy, as well as complications during and after delivery until discharge. Attending midwives or physicians are responsible for providing the information to the registry. Before 1998, information was based on free text descriptions, which were coded using the International Classification of Diseases (ICD), 8th version. After 1998, checkboxes were introduced in addition to free text, and ICD-10 used for coding. By means of the unique national identification number, assigned to all residents in the country, births from the same women were identified, keeping the mother as the unit of analysis. Data from the MBRN was linked to the Country-of-Origin Database at Statistics Norway and the National Education Database.

CD was the outcome variable and proportions were calculated by dividing the number of CD by the number of deliveries during the specific period per 100 births. To capture changes in reporting format and obstetric practices across decades, we divided the study years into three periods: (1967-1982), (1983-1998) and (1999-2014).

**Study population**

We used the Robson (R) classification to identify the study population (27). This tool stratifies women based on five obstetric parameters: number of fetuses, fetal presentation, gestational age, previous CD, and onset of labor. Our study population include “nulliparous term, cephalic, spontaneous labors” (R1), “nulliparous term, cephalic, induced” (R2a) and “nulliparous term, cephalic, pre-labor CD” (R2b). Similarly, to account for the acknowledged increased risk of CD in complicated pregnancies, women were stratified into lower- and higher-risk groups. Due to no direct information on indication for CD, we used the following complications as proxy for the indication: abruptio placenta, diabetes mellitus (before or during pregnancy), hypertension (chronic or during pregnancy), preeclampsia, postdate (>= 42 weeks), premature rupture of membranes (PROM: membrane rupture for > 24 hour and unspecified time) and placenta previa. We adopted the potential indication list from two prior hospital-based studies(30, 31). Women with none of the seven complications were classified as lower- risk and women with one or more of the complications as higher-risk women.

The study population included women who gave birth to their first singleton baby between 1967-2014. We excluded women with pregnancies ending before 22 completed weeks of gestation or where infant’s birthweight by gestational age Z score was less than -5 or greater than 5, (n=51,046)(32) and women with missing information on Robson classification (n=4637). Women in the other Robson groups (breech (R6), transverse presentation (R9) and preterm delivery (R10), n=102,832) were also excluded. The final study population included women with term, singleton, cephalic presentation (**Figure S1**). In analyses of CD recurrence risk, we included all women who gave birth to their first and second singleton baby, between 1967 and 2014.

**Statistical analysis**

Frequency and contingency tables were used to describe CD by sociodemographic factors, and analyses were stratified by lower- and higher-risk groups and onset of labor. Statistical analysis was carried out with STATA IC statistical software (version 16). Change in CD by maternal age groups and onset of labor were assessed during the three periods, 1967-1982, 1983-1998 and 1999-2014, in both risk groups. Generalized linear models with log link, binomial distribution and exponentiated regression coefﬁcients were used to calculate crude and adjusted relative risks (ARR) with 95% conﬁdence intervals (CI) by periods. P-values below 0.05 were considered significant. Variables included in the models were: maternal age (<20 (reference), 20-24, 25-29,30-34, 35-39 and >=40), maternal level of education (low: < 13 years and high: >=13 years (reference)), mother’s country of birth (group 1: Europe, Canada, USA, New Zealand, and Australia (reference), group 2: all other countries). We also tested the trend for CD within each category of maternal age, using time period age as a continuous variable.

Results

A total of 951,895 nulliparous women with singleton, cephalic, term births were included (**Figure S1**). The overall CD rate was 8.9%, increasing from 4.4% in 1967-1982 to 13.0% in 1999-2014. **Table 1** showssociodemographic changes across the three time periods. The proportion of women having their first birth >= 35 years increased from 1.6% in 1967-1982 to 8.4% in 1999-2014. Women having their first birth < 25 years decreased from 70% to 30% over the same periods. From first to last period, women with 13 years or more education more than doubled (from 25.8% to 54.3%) while the proportion of non-western women increased from 0.6% to 9.5%. Across periods, the proportion of women in R1 decreased from 86.2% to 81.3% while proportion of R2 women increased from 13.8 % to 18.7%. The proportion of higher-risk women increased from 23.6% in 1967-82 to 26.9% in 1999-2014. Risk factors that contributed the most to the higher-risk group were postdate, preeclampsia and PROM. Over the periods, the proportion of women with postdate decreased while women with PROM increased. Preeclampsia made up 14.8% of the higher-risk group overall, 12.3% in 1967-82 and 15.3% in 1999-2014.

In stratified analyses, 716,454 (75.2%) women were defined as lower- and 235,441 (24.8%) as higher-risk. Overall CD rates in lower-risk women increased from 3.3% in 1967-82 to 10.2% in 1999-2014, while it increased from 8.0% to 20.5% in higher-risk women (**Table S1**). In both risk groups, CD was least common in women < 20 years while most common in women >= 40 years. Women with low education and from countries in group 2 had increased risk of CD (not shown).

CD time trends differed by maternal age **(Figure 1).** Compared to women <20 years giving birth in 1967-82, the RR of CD increased across time periods in all age groups < 35 years while it was stable or decreased slightly in age groups >= 35 years, in both lower- risk (**Figure 1a)** and higher risk women (**Figure 1b**). Except for lower-risk women aged 35-39 years, P for trend was significant in each age group for both risk groups. Adjusting for maternal education and country of birth did not change our estimates.

CD rates by periods and onset of labor (R1, R2a, R2b) in strata of lower- and higher-risk women, are presented in **Figure 2**. In both risk groups, the proportion of women having CD following spontaneous onset of labor (R1) nearly tripled from 2.4% (1967-82) to 6.7% (1999-2014) in lower-risk women and from 5.9% to 14.3% in higher-risk women. In women with induced onset of labor (R2a), the CD rates doubled from 10.1% to 21.1% in lower-risk women and from 10.4% to 24.3% in higher-risk women. The number of nulliparous women having pre-labor CD increased in both risk groups (R2b). Across periods, the contribution of R2b to the total R2 group increased from 3.3% to 23.9 in lower-risk women and from 2.3% to 7% in higher-risk women.

The trends in ARR of CD increased in 1999-2014, compared to 1967-82, for all women (**Table S2**). ARR of CD in R1 in the last relative to first period, was 2.1 (95% CI, 2.0-2.2) in lower-risk women and 1.8 (95% CI 1.7-1.9) in higher-risk women. Across periods and risk groups, the ARR of CD was higher in R2a than R1. Compared to R1 in 1967-82, ARR of CD in R2a group increased from 3.8 (95% CI 3.6 -4.0) in period 1 to 6.0 (95% CI 5.7-6.2) in period 3 in lower-risk women and from 1.7 (95% CI 1.6-1.8) to 3.0 (95% CI 2.9-3.2) in higher-risk women. The ARR of CD in R2a decreased from the second to the last period, in both risk groups.

A total of 724,346 women delivered their first and second term, singleton baby in 1967-2014. Absolute and relative risks of CD in second birth among women with and without CD in their first birth, are presented in **Table 2**. Overall risk of CD in the second birth decreased (63% to 58.3%) in women with CD in first birth and it increased (2.8% to 6.6%) in women with no CD in first birth. The absolute risk of CD in the second birth among lower-risk women, following CD in first birth declined (from 66.2% to 58.3%) while it increased for women with no CD in first birth (from 2.6 % to 5.8%). In higher-risk women, the absolute risk of CD recurrence following CD in first birth did not change while it increased for women with no CD in first birth (from 3.6% to 8.5%). The RR of CD recurrence in all women, compared to women without CD in first birth, changed from 22.4 (95% CI 21.9-23.1) in 1967-82 to 8.8 (95% CI 8.6-9.1) in 1999-2014.

Discussion

**Main findings**

The prevalence of CD in nulliparous women increased across periods in both lower- and higher-risk women. Across periods, CD increased in women < 35 years while it was stable or decreased in both lower and higher-risk women >= 35 years. Compared to women with spontaneous onset, women with induced onset of labor had higher CD risk in both risk groups. The proportion of women with pre-labor CD among all women with either induced or pre-labor CD increased considerably more in lower-risk than higher-risk women, both on the absolute and the relative scale. Recurrence risk for CD was lower in the last than in the first period.

**Strength and Limitations**

Strengths of this study are the large sample size, the comprehensive prospective population follow-up over almost five decades, which make both selection bias and recall bias less likely. In addition, missing data were low for most variables (< below 4%), except for country of birth during 1967-82. However, missing values were evenly distributed by maternal age and education.

The study inherently has some limitations. Lack of data on the clinical indications for CD was handled by using pregnancy complications as a proxy for CD indication(30, 31). We did, however, not have information on the two most common indications for CD, fetal distress and failure to progress (30). Instead, we identified pregnancy complications that increase risk of both these two common indications. Sensitivity analyses verified the biological difference and risk of CD between the two groups as we found that higher-risk women had worse birth outcomes than lower-risk women **(Table S3).** Changes in the reporting format in the MBRN is another limitation. Unlike checkboxes, reporting from free text is prone to underreporting. Evaluation of the completeness of CD notification to the MBRN when compared to medical records at delivery units, showed a 3% error rate for the years before 1984(33). This will likely have biased our results towards the null. Likewise, validity of data on initiated onset of labor (induced or pre-labor CD) was poor before the mid-1980s(34). The registration and validity of these variables have considerably improved later and findings from the last period (1999-2014) offer more precise and valid results. The last period also reflects the current sociodemographic environment and clinical practice. Our findings may have underestimated changes for lower-risk women as the risk factors used to define the risk groups may have been underreported in the early years of the MBRN(29). Some women in the lower-risk group in the early period may have been higher-risk women. However, this means that the true change of CD in lower-risk women is likely larger than we reported here. Data on smoking and BMI were only available after 1999 and 2007, respectively.

**Interpretation**

Our study focused on nulliparous women with singleton, cephalic, term pregnancies. These women account for 90% of nulliparous and 40% of all reproductive women in Norway(28). The proportion of women aged >= 25 years at their first birth increased across the three periods. Advanced maternal age is strongly associated with higher risk of intrapartum primary CD due to increased risk of pregnancy complications(10, 16) and biological changes in uterine contractility(17, 18). However, we found that women aged <35 years had the highest increase in CD across periods.

Onset of labor was assessed to understand the contribution of change in provider practice and women’s preferences to CD trends. Overall risk of CD among women with spontaneous onset of labor doubled in the lower-risk while it increased by 82% in higher-risk women. In line with other studies, risk of CD was higher in women with induced labor than women with spontaneous onset of labor (21, 22, 35, 36). Risk of CD following induction increased, with one in five induced women having CD in 1999-2014, similar to the findings by Sørbye(31). This is important regarding to the ongoing demographic shift in the reproductive population of women. Bergholt and colleagues reported that for every five-year increase in women’s age, the risk of CD increases 3 to 5 times for women with induced labor(36). In contrast, other studies found similar or decreased frequency of CD in the induced group(23-26).

Change in women’s preferences(15) and risk profile(13, 14) are other factors contributing to increased CD. We found an increase in the proportion of R2b/R2 in the last relative to the first period, and the change over time was much larger in lower-risk women than higher-risk women. This increment could not be explained by the seven pregnancy complications or other obstetric indications (preterm, breech or multifetal pregnancies). It could be due to increased fear of giving birth or that women want CD for other reasons, without any evident medical or pregnancy complications. Other complications not captured by our list may also explain some of this increment. A study from eight countries identified a knowledge gap and misconceptions about childbirth was frequent in women who requested CD(15). One out of 10 Norwegian women seemed to request CD(37) with fear of pain, physical damages, and fear of lacking support during delivery being main reasons(38, 39). The recent increment in overweight and obesity in Norway, may also affect CD rates for all women(28). In Denmark, prevalence of overweight and obesity, between 2004-2015, was higher in women >=35 than younger women(12).

This study confirmed women’s age to be associated with the risk of CD. Adjustment for other factors including biological (lower-higher-risk), sociodemographic factors (education, mothers’ country of birth) did not alter the associations. This adds to a growing evidence supporting a causal association between maternal age and CD(9, 12, 13, 17). However, what is interesting is that risk of CD declined in all women >= 40 years during the study period. Women who have their first birth at advanced age are usually educated, affluent and with better socioeconomic support and with less risk factors such as smoking and overweight(10, 16, 40, 41). Although women aged 35 and older grew up in an era when smoking was more prevalent, smoking prevalence is found to be lower in this group(42). Similar CD trends were also reported in Sweden(19) and Canada(13).

A shift where CD is becoming more common among younger and lower-risk nulliparous women is concerning. In Norway, the majority of women (84%) have two or more births(43). However, we found a reduction in CD recurrence risk in the last period. This suggests an important scope with tackling high rates in subsequent births. The less medicalized approach to childbirth in the Nordic countries where majority of births are attained by mid-level health professionals(2), might reduce unnecessary intervention. This principle could also explain the low primary and recurrent CD rates in Norway compared to other developed countries(1, 3, 4, 13).

As women with nulliparous, singleton, cephalic term birth represents 40% of the population giving birth, a strong focus and attention should be put in to reduce CD in this population. Policy makers and clinicians need to adapt measures that can decrease CD in women with low education, from non-western countries and reduce the number of women requesting for CD. Future research assessing the impact of current CD trends on long-term women’s health are recommended.

Conclusion

Overall CD increased in Norwegian nulliparous women < 35 years, both in the lower- and higher-risk group, while it was stable or decreased in women >= 35 years. The increase in intervention (induction and pre-labor CD) was associated with increased CD rates and was considerably more in lower-risk than higher-risk women. Overall risk of CD recurrence, however, declined over 47 years.

**Details of ethics approval**

This study was approved in Norway by the Regional Ethics Committee REK VEST 2015/1728 (approval date November 5/2015) and 16/11088 (approval date January 21/2021). All data handled by the researchers were anonymous, and as we did not have additional patient contact, individual consent was not required for the use of these compulsory collected national data.

**Contribution to Authorship**

YTS, LMS and RS designed this study. YTS analyzed the data, wrote the draft manuscript and is responsible for the reviewing and editing of the manuscript. LMS, LGK and NHM reviewed and commented on results. LMS, LGK, NHM, RS and KK contributed with critical comments to the analyses, writing and reviewing of this manuscript. RS is guarantor for data quality.

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References

1. Health at a Glance 2019: OECD indicators 2019 [Available from: <https://www.oecd-ilibrary.org/sites/fa1f7281-en/index.html?itemId=/content/component/fa1f7281-en#:~:text=Across%20OECD%20countries%2C%2028%25%20of,five%20years%20(Figure%209.17>).

2. Pyykönen A, Gissler M, Løkkegaard E, Bergholt T, Rasmussen SC, Smárason A, et al. Cesarean section trends in the Nordic Countries – a comparative analysis with the Robson classification. Acta Obstetricia et Gynecologica Scandinavica. 2017;96(5):607-16.

3. Ananth CV, Friedman AM, Keyes KM, Lavery JA, Hamilton A, Wright JD. Primary and Repeat Cesarean Deliveries: A Population-based Study in the United States, 1979-2010. Epidemiology (Cambridge, Mass). 2017;28(4):567-74.

4. Davey M, King J. Caesarean section following induction of labour in uncomplicated first births- a population-based cross-sectional analysis of 42,950 births. BMC Pregnancy Childbirth. 2016;16:92.

5. Keag O, Norman J, Stock S. Long-term risks and benefits associated with cesarean delivery for mother, baby, and subsequent pregnancies: Systematic review and meta-analysis. PLoS Med. 2018;15(1):e1002494.

6. Kietpeerakool C, Lumbiganon P, Laopaiboon M, Rattanakanokchai S, Vogel JP, Gülmezoglu AM. Pregnancy outcomes of women with previous caesarean sections: Secondary analysis of World Health Organization Multicountry Survey on Maternal and Newborn Health. Scientific Reports. 2019;9(1):9748.

7. Petrou S, Glazener C. The economic costs of alternative modes of delivery during the first two months postpartum: results from a Scottish observational study. BJOG. 2002;109(2):214-7.

8. Vogel JP, Betrán AP, Vindevoghel N, Souza JP, Torloni MR, Zhang J, et al. Use of the Robson classification to assess caesarean section trends in 21 countries: a secondary analysis of two WHO multicountry surveys. Lancet Glob Health. 2015;3(5):e260-70.

9. Bayrampour H, Heaman M. Advanced maternal age and the risk of cesarean birth: a systematic review. 2010;37(3):219-26.

10. Luke B, Brown MB. Elevated risks of pregnancy complications and adverse outcomes with increasing maternal age. Hum Reprod. 2007;22(5):1264-72.

11. Richards MK, Flanagan MR, Littman AJ, Burke AK, Callegari LS. Primary cesarean section and adverse delivery outcomes among women of very advanced maternal age. Journal of Perinatology. 2016;36(4):272-7.

12. Rydahl E, Declercq E, Juhl M, Maimburg RD. Cesarean section on a rise-Does advanced maternal age explain the increase? A population register-based study. PloS one. 2019;14(1):e0210655-e.

13. Wood S, Tang S. Changes in the Frequency of Cesarean Delivery in Nulliparous Women in Labor in a Canadian Population, 1992-2018. Obstet Gynecol. 2021;137(2):263-70.

14. Bergholt T, Lim L, Jørgensen J, Robson M. Maternal body mass index in the first trimester and risk of cesarean delivery in nulliparous women in spontaneous labor. Am J Obstet Gynecol. 2007;196(2):163.e1-5.

15. Stoll KH, Hauck YL, Downe S, Payne D, Hall WA, Gross M, et al. Preference for cesarean section in young nulligravid women in eight OECD countries and implications for reproductive health education. Reproductive Health. 2017;14(1):116.

16. Joseph KS, Allen AC, Dodds L, Turner LA, Scott H, Liston R. The perinatal effects of delayed childbearing. Obstet Gynecol. 2005;105(6):1410-8.

17. Smith GCS, Cordeaux Y, White IR, Pasupathy D, Missfelder-Lobos H, Pell JP, et al. The effect of delaying childbirth on primary cesarean section rates. PLoS medicine. 2008;5(7):e144-e.

18. Main DM, Main EK, Moore DH, 2nd. The relationship between maternal age and uterine dysfunction: a continuous effect throughout reproductive life. Am J Obstet Gynecol. 2000;182(6):1312-20.

19. Waldenström U, Gottvall K, Rasmussen S. Caesarean section in nulliparous women of advanced maternal age has been reduced in Sweden and Norway since the 1970s: a register-based study. BJOG. 2012;119(13):1591-6.

20. Hannah ME, Hannah WJ, Hewson SA, Hodnett ED, Saigal S, Willan AR. Planned caesarean section versus planned vaginal birth for breech presentation at term: a randomised multicentre trial. The Lancet. 2000;356(9239):1375-83.

21. Ehrenthal DB, Jiang X, Strobino DM. Labor Induction and the Risk of a Cesarean Delivery Among Nulliparous Women at Term. Obstetrics & Gynecology. 2010;116(1).

22. Jonsson M, Cnattingius S, Wikström A-K. Elective induction of labor and the risk of cesarean section in low-risk parous women: a cohort study. Acta Obstetricia et Gynecologica Scandinavica. 2013;92(2):198-203.

23. Dögl M, Vanky E, Heimstad R. Changes in induction methods have not influenced cesarean section rates among women with induced labor. Acta Obstetricia et Gynecologica Scandinavica. 2016;95(1):112-5.

24. Grobman WA, Rice MM, Reddy UM, Tita ATN, Silver RM, Mallett G, et al. Labor Induction versus Expectant Management in Low-Risk Nulliparous Women. New England Journal of Medicine. 2018;379(6):513-23.

25. Rydahl E, Declercq E, Juhl M, Maimburg RD. Routine induction in late-term pregnancies: follow-up of a Danish induction of labour paradigm. BMJ open. 2019;9(12):e032815.

26. Stock SJ, Ferguson E, Duffy A, Ford I, Chalmers J, Norman JE. Outcomes of elective induction of labour compared with expectant management: population based study. Bmj. 2012;344:e2838.

27. Robson MS. Classification of caesarean sections. Fetal and Maternal Medicine Review. 2001;12(1):23-39.

28. FHI. Birth statistics 2014 [Available from: <https://www.fhi.no/en/hn/health-registries/medical-birth-registry-of-norway/medical-birth-registry-of-norway/>.

29. Irgens LM. The Medical Birth Registry of Norway. Epidemiological research and surveillance throughout 30 years. Acta Obstetricia et Gynecologica Scandinavica. 2000;79(6):435-9.

30. Kolås T, Hofoss D, Daltveit AK, Nilsen ST, Henriksen T, Häger R, et al. Indications for cesarean deliveries in Norway. Am J Obstet Gynecol. 2003;188(4):864-70.

31. Sørbye IK, Oppegaard KS, Weeks A, Marsdal K, Jacobsen AF. Induction of labor and nulliparity: A nationwide clinical practice pilot evaluation. Acta Obstetricia et Gynecologica Scandinavica. 2020.

32. SKJÆRVEN R, GJESSING HK, BAKKETEIG LS. Birthweight by gestational age in Norway. Acta Obstetricia et Gynecologica Scandinavica. 2000;79(6):440-9.

33. Borthen I, Lossius P, Skjaerven R, Bergsjø P. Changes in frequency and indications for cesarean section in Norway 1967-1984. Acta Obstetricia et Gynecologica Scandinavica. 1989;68(7):589-93.

34. Moth FN, Sebastian TR, Horn J, Rich-Edwards J, Romundstad PR, Åsvold BO. Validity of a selection of pregnancy complications in the Medical Birth Registry of Norway. Acta Obstetricia et Gynecologica Scandinavica. 2016;95(5):519-27.

35. LeRay C, Carol M, Breat G, Goffinet F, GROUP FTPS. Elective induction of labor: failure to follow guidelines and risk of cesarean delivery. Acta Obstetricia et Gynecologica Scandinavica. 2007;86(6):657-65.

36. Bergholt T, Skjeldestad FE, Pyykonen A, Rasmussen SC, Tapper AM, Bjarnadottir RI, et al. Maternal age and risk of cesarean section in women with induced labor at term-A Nordic register-based study. Acta Obstet Gynecol Scand. 2020;99(2):283-9.

37. Kringeland T, Daltveit AK, Møller A. What characterizes women in Norway who wish to have a caesarean section? Scand J Public Health. 2009;37(4):364-71.

38. Eide KT, Morken N-H, Bærøe K. Maternal reasons for requesting planned cesarean section in Norway: a qualitative study. BMC Pregnancy and Childbirth. 2019;19(1):102.

39. Wiklund I, Edman G, Andolf E. Cesarean section on maternal request: reasons for the request, self-estimated health, expectations, experience of birth and signs of depression among first-time mothers. Acta Obstetricia et Gynecologica Scandinavica. 2007;86(4):451-6.

40. Nilsen AB, Waldenström U, Hjelmstedt A, Rasmussen S, Schytt E. Characteristics of women who are pregnant with their first baby at an advanced age. Acta Obstetricia et Gynecologica Scandinavica. 2012;91(3):353-62x.

41. Klemetti R, Gissler M, Sainio S, Hemminki E. Associations of maternal age with maternity care use and birth outcomes in primiparous women: a comparison of results in 1991 and 2008 in Finland. BJOG. 2014;121(3):356-62.

42. Kvalvik L, Skjaerven R, Haug K. Smoking during pregnancy from 1999 to 2004: a study from the Medical Birth Registry of Norway. Acta Obstetricia et Gynecologica Scandinavica. 2008;87(3):280-5.

43. Skjaerven R, Wilcox AJ, Klungsøyr K, Irgens LM, Vikse BE, Vatten LJ, et al. Cardiovascular mortality after pre-eclampsia in one child mothers: prospective, population based cohort study. Bmj. 2012;345:e7677.

**Table 1.** Cesarean delivery rates and maternal characteristics at first singleton, cephalic, term birth (Robson group 1 and 2), by three time periods in Norway, the Medical Birth Registry of Norway, 1967-2014 (n=951,895)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **1967-1982** | | **1983-1998** | | **1999-2014** | |
| **Variables** | **N** | **%** | **N** | **%** | **N** | **%** |
| **Mode of delivery: Cesarean Delivery** |  |  |  |  |  |  |
| Yes | 14538 | 4.4 | 28709 | 9.4 | 41270 | 13.0 |
| No | 313995 | 95.6 | 276349 | 90.6 | 277034 | 87.0 |
| **Maternal age (years)** |  |  |  |  |  |  |
| <20 | 66012 | 20.1 | 27500 | 9.0 | 15348 | 4.8 |
| 20-24 | 163490 | 49.8 | 114519 | 37.5 | 77651 | 24.4 |
| 25-29 | 76681 | 23.3 | 113389 | 37.2 | 122059 | 38.4 |
| 30-34 | 17173 | 5.2 | 39244 | 12.9 | 76662 | 24.1 |
| 35-39 | 4259 | 1.3 | 9195 | 3.0 | 22818 | 7.2 |
| >=40 | 918 | 0.3 | 1211 | 0.4 | 3766 | 1.2 |
| **Maternal education (years)** |  |  |  |  |  |  |
| Low (≤ 13) | 241400 | 73.5 | 174713 | 57.3 | 133554 | 42.0 |
| High (>13) | 84918 | 25.8 | 127689 | 41.9 | 172968 | 54.3 |
| Missing | 2215 | 0.7 | 2656 | 0.9 | 11782 | 3.7 |
| **Maternal country of birth** |  |  |  |  |  |  |
| Group 1 | 254198 | 77.4 | 270717 | 88.7 | 283329 | 89.0 |
| Group 2 | 1751 | 0.6 | 10443 | 3.4 | 30283 | 9.5 |
| Missing | 72335 | 22.0 | 23898 | 7.8 | 4692 | 1.5 |
| **Robson groups** |  |  |  |  |  |  |
| R1 | 283262 | 86.2 | 258664 | 84.8 | 258950 | 81.3 |
| R2 | 45271 | 13.8 | 46394 | 15.2 | 59354 | 18.7 |
| **Risk groups** |  |  |  |  |  |  |
| Lower-risk | 251012 | 76.4 | 232628 | 76.3 | 232814 | 73.1 |
| Higher-risk | 77521 | 23.6 | 72430 | 23.7 | 85490 | 26.9 |
| **Pregnancy complications¤** |  |  |  |  |  |  |
| Abruptio placenta | 885 | 1.1 | 1050 | 1.4 | 568 | 0.7 |
| Diabetes mellitus (before and during pregnancy) | 428 | 0.6 | 1737 | 2.4 | 6026 | 7.0 |
| Hypertension (before and during pregnancy | 6400 | 8.2 | 5572 | 7.7 | 8496 | 9.9 |
| Placenta previa | 261 | 0.3 | 276 | 0.4 | 430 | 0.5 |
| Preeclampsia | 9527 | 12.3 | 12152 | 16.8 | 12745 | 15.2 |
| Premature rupture of membrane | 3487 | 4.5 | 4735 | 6.5 | 30657 | 35.9 |
| Postdate | 59771 | 77.3 | 50727 | 70.1 | 33371 | 39.0 |
| **Total** | 328533 | 100.0 | 305058 | 100.0 | 318304 | 100.0 |

¤: among higher-risk women only

**Table 2**. Absolute risk and adjusted relative risks (ARR) of cesarean delivery recurrence in second birth among women with their two first singleton babies in 1967-2014, according to cesarean delivery in their first birth. Norway, 1967-2014 (n= 724,346)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Lower-risk women** | | | | |
|  | **Risk of CD¤ in second pregnancy** | | |  | **Relative risk of CD in second pregnancy** |
| **Year of birth** | **Women with CD in first** | **%** | **Women with No CD in first** | **%** | **ARR a (95 % CI)** |
| **1967-1982** | 4024/6157 | 65.4 | 5330/206082 | 2.6 | 25.3 (24.5-26.1) |
| **1983-1998** | 7071/12698 | 55.7 | 9191/180519 | 5.1 | 10.9 (10.7-11.2) |
| **1999-2014** | 7210/12341 | 58.4 | 7313/130822 | 5.6 | 10.5 (10.2-10.7) |
| **Total b** | 18305/31196 | 58.7 | 21834/517423 | 4.2 | 12.4 (12.2-12.7) |
|  | **Higher-risk women** | | | | |
|  | **Risk of CD in second pregnancy** | | |  | **Relative risk of CD in second pregnancy** |
| **Year of birth** | **Women with CD in first** | **%** | **Women with No CD in first** | **%** | **ARR a (95 % CI)** |
| **1967-1982** | 2666/4816 | 59.8 | 2150/60300 | 3.6 | 16.8 (16.0-17.6) |
| **1983-1998** | 4605/8032 | 53.2 | 3427/51163 | 6.7 | 7.9 (7.6-8.2) |
| **1999-2014** | 5406/8966 | 59.0 | 3560/41975 | 8.5 | 6.9 (6.7-7.2) |
| **Total b** | 12677/21814 | 56.9 | 9137/153438 | 6.0 | 8.4 (8.2-8.6) |
|  | **All women** | | | | |
|  | **Risk of CD in second pregnancy** | | |  | **Relative risk of CD in second pregnancy** |
| **Year of birth** | **Women with CD in first** | **%** | **Women with No CD in first** | **%** | **ARR a (95 % CI)** |
| **1967-1982** | 6690/10615 | 63.0 | 7480/266382 | 2.8 | 22.4 (21.9-23.1) |
| **1983-1998** | 11676/21361 | 54.7 | 12618/231682 | 5.4 | 10.0 (9.8-10.2) |
| **1999-2014** | 12616/21509 | 58.7 | 10873/172797 | 6.3 | 8.8 (8.6-9.1) |
| **Total b** | 30982/53485 | 57.9 | 30971/670861 | 4.6 | * 1. (10.9-11.3) |

¤: Cesarean delivery

a Relative to women without history of CD in first birth

b Overall RR adjusted for maternal age, maternal education, mother’s country of birth and year of first birth.

\* Women with any of the seven pregnancy complications: abruptio placenta, diabetes mellitus (before or during pregnancy), hypertension (before or during pregnancy), preeclampsia, postdate, premature rapture of membrane (membrane rupture for > 24 hour and unspecified time) and placenta previa

\*\* Women with none of the seven complications

Figure Caption List

**Figure 1**. Relative risk (RR) of cesarean delivery in nulliparous women by maternal age and risk groups, Norway, 1967-2014 (n=951 895)

**Figure1 a**. Relative risk (RR) of cesarean delivery in lower-risk\*\* nulliparous women by maternal age, Norway, 1967-2014 (n=716 454)

**Figure1 b.** Relative risk (RR) of cesarean delivery in higher-risk\* nulliparous women by maternal age, Norway, 1967-2014 (n=235 441)

\* Women with any of the seven pregnancy complications: abruptio placenta, diabetes mellitus (before or during pregnancy), hypertension (before or during pregnancy), preeclampsia, postdate, premature rapture of membrane (membrane rupture for > 24 hour and unspecified time) and placenta previa

\*\* Women with none of the seven complications

¤ RR are crude, adjusting for maternal education and country of birth did not change estimates.

**Figure 2.** Proportion of cesarean delivery in nulliparous women by Robson and risk group, Norway, 1967-2014 (N= 951895)

R1: Spontaneous onset of labor

R2a: Onset of labor by induction

R2b: Pre-labor cesarean delivery, total number of R2b divided by total number of R2

R2: Summation of R2a and R2b

\* Women with any of the seven pregnancy complications: abruptio placenta, diabetes mellitus (before or during pregnancy), hypertension (before or during pregnancy), preeclampsia, postdate, premature rapture of membrane (membrane rupture for > 24 hour and unspecified time) and placenta previa

\*\* Women with none of the seven complications

Supplementary Appendix

**Figure S1.** Flowchart of study population.

¤ Robson group stratifies women based on five obstetric parameters: number of fetuses, fetal presentation, gestational age, previous cesarean delivery and onset of labor.

**Table S1.** The proportion of cesarean delivery among nulliparous women by maternal age and time period, stratified by lower- and higher-risk women.

**¤** Total number of CD within the specific age group divided by total deliveries in the specific age group.

\* Women with any of the seven pregnancy complications: abruptio placenta, diabetes mellitus (before or during pregnancy), hypertension (before or during pregnancy), preeclampsia, postdate, premature rapture of membrane (membrane rupture for > 24 hour and unspecified time) and placenta previa

\*\* Women with none of the seven complications

**Table S2.** Cesarean delivery among nulliparous women by Robson groups and time period, stratified by lower- and higher-risk women.

**¤** Total number of CD within the specific age group divided by total deliveries in the specific age group.

R1: Spontaneous onset of labor

R2a: Onset of labor by induction

R2b: Pre-labor cesarean delivery

R2: Summation of R2a and R2b

a Relative to R1 group in period 1

b adjusted for maternal age, maternal education and mother’s country of birth.

\* Women with any of the seven pregnancy complications: abruptio placenta, diabetes mellitus (before or during pregnancy), hypertension (before or during pregnancy), preeclampsia, postdate, premature rapture of membrane (membrane rupture for > 24 hour and unspecified time) and placenta previa

\*\* Women with none of the seven complications

#: Not applicable

**Table S3**. Birth outcomes in lower- and higher-risk nulliparous women with term singleton, cephalic deliveries.

**#** The first 24 hours

**¤** Appearance, Pulse, Grimace, Activity, and Respiration

\* Women with any of the seven pregnancy complications: abruptio placenta, diabetes mellitus (before or during pregnancy), hypertension (before or during pregnancy), preeclampsia, postdate, premature rapture of membrane (membrane rupture for > 24 hour and unspecified time) and placenta previa

\*\* Women with none of the seven complications