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Health outcomes up to 5 years in children born as a second child after a previous caesarean section in a first pregnancy: a Swedish population-based register study between 1999 and 2015

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ABSTRACT

Objective To explore health outcomes up to 5 years of age, according to mode of birth, in a large cohort of Swedish children who were born as a second child to women who had a caesarean section (CS) in their first pregnancy.

Design Retrospective population-based register study.

Population All children (n=94 498) who were born as a second child (or children in cases of twins or higher-order multiple births) during 1999–2015 in Sweden in women who had a CS first birth. The children were followed up to 5 years of age. For inclusion, both births must have occurred in Sweden.

Methods A nationwide cohort study using follow-up data up to 5 years of age. Maternal factors, including age, smoking, diabetes, obesity (body mass index ≥30), mental illness, pre-eclampsia, education, income, country of birth and the neonatal factors of being a singleton and prematurity (up to week 36+6) were adjusted for in regression models.

Main outcome measures Developmental problems, asthma, allergy, hospital care and death within 5 years of age.

Results A total of 94 498 children were included in the study. Risk for developmental problems, asthma and allergy was increased after repeat CS but not after vaginal birth. The need for hospital care was increased in all other birth modes compared with spontaneous vaginal birth. The risk of death within 5 years increased after instrumental vaginal birth and emergency repeat CS.

Conclusions All repeat CS compared with spontaneous vaginal birth was related to increased risks for developmental problems, asthma, allergy and hospital stay, and emergency repeat CS was associated with an increased risk of death within 5 years. The results of the present study support vaginal birth as the optimal mode of birth after previous CS for longer-term child health outcomes.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Caesarean section (CS) rates are increasing globally, and several studies have shown increased risk of childhood asthma following CS. Developmental problems following CS are also suggested, although further studies are needed.

WHAT THIS STUDY ADDS

⇒ The risk for childhood asthma, allergy and developmental problems was increased up to 5 years following elective and emergency repeat CS, compared with spontaneous vaginal birth in children who were born as a second child to women who gave birth to their first baby by CS.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The results of the present study support vaginal birth as the preferred mode of birth after previous CS for optimising child health outcomes up to 5 years.

INTRODUCTION

Caesarean section (CS) rates are increasing globally, with more than 20% of all women currently giving birth via CS. This trend is anticipated to continue, with the rate of CS estimated to increase to around 30% by 2030.[1] CS rates internationally, however, are varied with averages ranging from 5% in sub-Saharan Africa to over 40% in Latin America and the Caribbean. CS has risen in all regions and subregions with the greatest increases seen in Eastern Asia, Western Asia and Northern Africa.[1] CS, for some women and their babies, is a lifesaving procedure, performed to prevent or reduce adverse perinatal outcomes. In all cases, however, high CS rates do not necessarily correspond with better maternal and neonatal outcomes, and, contrastingly, can lead to risks, including risks of infection and haemorrhage, which contribute to overall increased maternal mortality, longer postpartum recovery, longer hospital stay for the mother and lower breastfeeding rates compared with vaginal birth.[2 3]

In this regard, concerns continue to exist that many CS are being performed unnecessarily.[4 5]

Although not optimal for all women, repeat CS is common and has been considered a safe option for the baby.[6] Still, CS has been associated with increased respiratory morbidity and higher risks for transient tachypnoea of the newborn, compared with vaginal birth.[7] Gut microbiota in children has been of interest for the development of allergy,[8] and it has been speculated that a lower diversity in microbiota early in life among children born by CS could be a pathogenetic factor contributing to allergic development.[9] Previous studies, including systematic reviews and meta-analyses,[10 11] have found increased risks of developing asthma, gastroenteritis symptoms, diabetes and high body mass index (BMI) among children born by CS.[10–16]

Relationship between CS and neurodevelopment is less certain and difficult to delineate, and earlier evidence is inconclusive. Because many women undergo unscheduled CS, there are challenges with demonstrating what longer-term outcomes are related to the mode of birth from those that are related to possible problems during labour. Furthermore, pre-existing differences between the groups undergoing planned CS may exist and could affect outcomes.

A meta-analysis of 20 million births in 19 countries demonstrated increased risks for autism and attention deficit hyperactivity disorder (ADHD), but not for cognitive and learning disorders after CS.[17] In an earlier Swedish prospective observational study, parents of children born by prelabour CS scored their children lower on a development scale at 4 months of age, compared with vaginally born controls, but at 12 months, most differences between groups did not remain, and longer-term outcomes were not reported.[18] In a data-linked Scottish cohort study, unscheduled repeat CS was associated with an increased risk of learning disability after emergency CS, but not after planned repeat CS.[19] Lower scores in gross and fine motor development at 5 months after CS were found in a Chinese study,[16] but contrastingly, a large European study involving preterm infants could not detect any differences in neurodevelopment at 2 years of age in relation to mode of birth.[20] Also, a Scottish register study did not find clear evidence of special educational needs in children born after planned repeat CS, compared with planned vaginal birth after caesarean (VBAC).[21]

In an earlier publication, we studied neonatal outcomes within 28 days in women's subsequent births to a first birth that was a CS in Sweden between the years of 1999 and 2015.[22] The results showed that following a previous birth by CS, spontaneous vaginal birth in the subsequent pregnancy was associated with better neonatal outcomes within 28 days after birth, compared with all other modes of birth.

As the increasing trend in CS appears set to continue, it is timely and important to understand short- and long-term outcomes for both mother and baby, with a need for large studies regarding the longer-term health outcomes in children in relation to mode of birth. The aim of this study was thus to explore health outcomes up to 5 years of age, according to mode of birth, in a large cohort of Swedish children who were born in a second parity to women who had a CS in their first pregnancy.

METHODS

Study design

A large nationwide population cohort study using follow-up data up to 5 years of age was conducted. Population-based data from the national registers of the Swedish Medical Birth Register, Statistics Sweden, the Swedish National Patient Register and the Cause of Death Register were accessed. Data were linked with a pseudonymized identification code for each person. Medical diagnoses were registered with the International Classification for Diseases 10th revision (ICD-10) codes. Data sources for all used variables are shown in online supplemental table S1.

The Swedish Medical Birth Register (MBR) includes around 98% of all births in Sweden. From 1982 onwards, the MBR is based on prospectively recorded information in standardised antenatal, obstetric and neonatal records. The overall quality of the MBR is very high, owing to the semiautomated data extraction from the standardised regional electronic health records, Sweden's universal access to antenatal care and the possibility of comparing mothers and offspring to the Total Population Register to identify missing records. Through the unique personal identity number of mothers and live-born offspring, the MBR can be linked to other health registers.[23]

Statistics Sweden is the Swedish government agency responsible for official national statistics, including the Total Population Register, and coordinates the system for official statistics in Sweden.

The Swedish National Patient Register contains information with high quality on completed inpatient stays nationwide since 1987 where more than 99% of all hospital stays are registered, including both somatic and psychiatric hospital care. The register also includes data on individuals treated by doctors in specialised outpatient care since 2001.[24]

The Swedish Cause of Death Register is a high-quality, virtually complete register of all deaths in Sweden since 1952.[25]

Setting

Maternity care in Sweden is free of charge and funded by taxes, and almost all births occur in hospitals. According to the law, women should be involved in all decisions regarding their care. However, the final decision about the mode of birth after a previous CS is made by obstetricians. Generally, women are not facilitated to have a planned CS in the absence of a medical reason for it. In some cases, such as fear of birth, a planned CS can be performed without medical reasons, after counselling

with the doctor responsible. After birth, the child is examined by care providers in child health centres, also free of charge. Almost all children in the country have regular follow-up assessments, for example, at 4 years of age.

Study population

The study population consisted of all children (n=94 498) who were born as a second child (or children in cases of twins or higher-order multiple births) during 1999–2015 in Sweden in women who had a CS first birth. Children born between 1999 and 2012 were followed up to 5 years of age. Due to follow-up time restricted to the end of 2017 in the Swedish National Patient Register and to the end of 2018 in the Swedish National Cause of Death Register, children who were born in 2013, 2014 and 2015 were followed up for 4, 3 and 2 years, respectively. For all children in the study population, 98.9% of mothers still lived in Sweden in December 2015. For inclusion, both births must have occurred in Sweden.

Exposure and covariates

The exposure considered in this study is the mode of birth, which was defined using variables from MBR, indicating if the birth was spontaneous vaginal, instrumental vaginal (vacuum or forceps) or CS. CS was further divided into elective and emergency CS. In some CS cases, information about being an elective or emergency CS was lacking, and thus, these cases were not included in the study (figure 1).

Characteristics of the children and mothers were considered, including maternal age, maternal smoking status at the beginning of pregnancy, maternal diabetes (self-reported to midwife), maternal obesity (height and weight measured at the beginning of pregnancy), pre-eclampsia (diagnosis codes at birth), maternal psychological disorder (diagnosis codes at birth), maternal education level (before birth), maternal socioeconomic status (disposable income per consumption unit in the family before birth), neonatal prematurity (gestational age up to week 36+6) and being a singleton pregnancy or not. Data sources and variables used are shown in online supplemental table S1. Included in the study population were 1285 pairs of twins, 21 sets of triplets and 1 set of quadruplets. Maternal characteristics are shown in table 1.

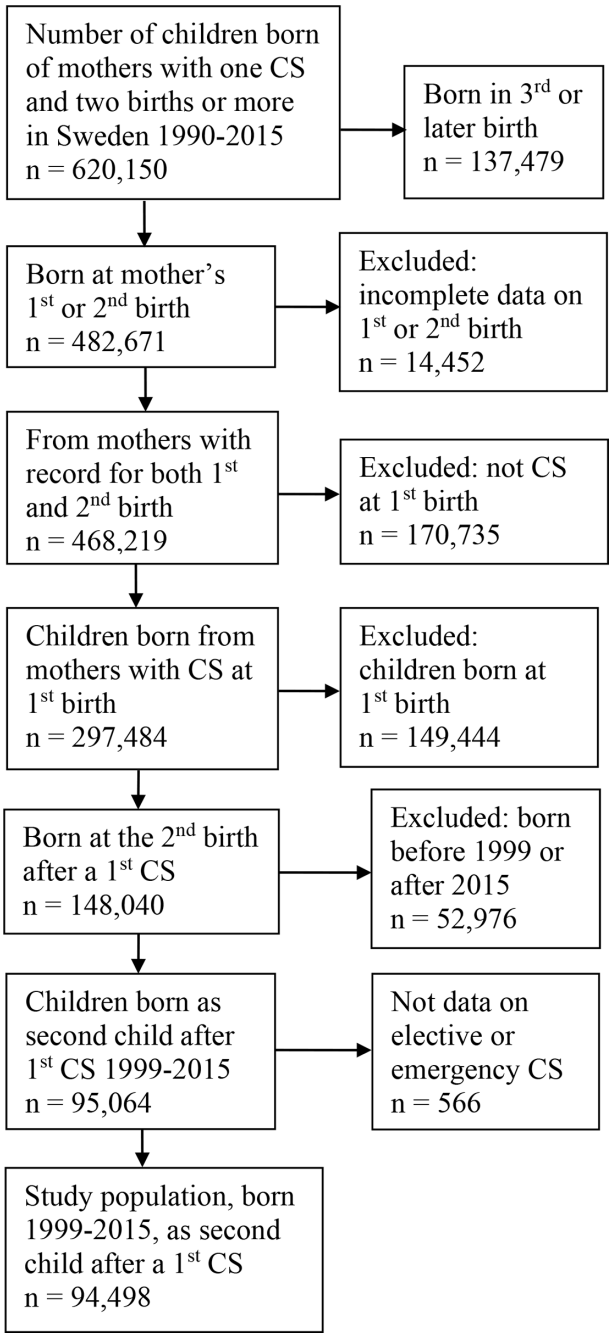

Figure 1 Flowchart over study population. CS, caesarean section.

Outcomes

Health variables measured up to 5 years of age included developmental problems (ICD-10 codes F80-F89), asthma (ICD-10 codes J40-J47), allergy (ICD-10 code T78), hospital care from birth up to 5 years of age (any cause) and death (any cause). Descriptions of diagnose codes are shown in table 2.

Statistical analysis

The effect of mode of birth on the outcomes was analysed using unadjusted and adjusted Poisson regressions, where relative risks (RR) with 95% CIs were presented. Covariates listed above were included in the adjusted models, and missing values were coded as '999' so they formed an 'unknown' group and were not excluded from the adjusted analysis. Statistical significance refers to $p<0.05$ (two-sided). All analyses were performed in STATA17 (StataCorp, Texas, USA).

Sensitivity analysis

Given that some data sources ended in 2017 or 2018 (online supplemental table S1), not all children were followed to exactly 5 years of age. We, therefore, performed a sensitivity analysis where only children born between 1999 and 2012 were included (n=74 986) to facilitate a complete 5-year follow-up analysis. The

Table 1 Maternal characteristics of the study population (n=94 498) versus mode of birth

	Spontaneous vaginal birth	Vacuum/forceps	Elective CS	Emergency CS	Total
N (%)	**34 030 (36.0)**	**8082 (8.6)**	**30 335 (32.1)**	**22 051 (23.3)**	**94 498 (100.0)**
Maternal age in years, mean (SD)	31.11 (4.44)	32.07 (4.29)	32.78 (4.72)	32.22 (4.58)	31.99 (4.61)
Smoking at the first antenatal care visit					
Yes	1893 (5.6)	381 (4.7)	1775 (5.9)	1260 (5.7)	5309 (5.6)
No	30 475 (89.6)	7314 (90.5)	26 907 (88.7)	19 524 (88.5)	84 220 (89.1)
Missing	1662 (4.9)	387 (4.8)	1653 (5.4)	1267 (5.7)	4969 (5.3)
Diabetes (type I or type II)	192 (0.6)	92 (1.1)	647 (2.1)	507 (2.3)	1438 (1.5)
BMI					
<30	26 828 (78.8)	6504 (80.5)	22 685 (74.8)	15 608 (70.8)	71 625 (75.8)
≥30	4206 (12.4)	861 (10.7)	4738 (15.6)	4415 (20.0)	14 220 (15.0)
Missing	2996 (8.8)	717 (8.9)	2912 (9.6)	2028 (9.2)	8653 (9.2)
Diagnosis of mental illness in maternal records	269 (0.8)	75 (0.9)	515 (1.7)	282 (1.3)	1141 (1.2)
Diagnosis of pre-eclampsia (within O14 ICD10)	757 (2.2)	189 (2.3)	565 (1.9)	1810 (8.2)	3321 (3.5)
Socioeconomic status					
High	6282 (18.5)	1670 (20.7)	7177 (23.7)	4055 (18.4)	19 184 (20.3)
Medium	14 964 (44.0)	3605 (44.6)	12 729 (42.0)	9275 (42.1)	40 573 (42.9)
Low	12 760 (37.5)	2796 (34.6)	10 401 (34.3)	8695 (39.4)	34 652 (36.7)
Missing	24 (0.1)	11 (0.1)	28 (0.1)	26 (0.1)	89 (0.1)
Maternal education completed					
University level/ tertiary school	17 421 (51.2)	4303 (53.2)	15 225 (50.2)	10 532 (47.8)	47 481 (50.2)
Secondary school	13 640 (40.1)	3208 (39.7)	12 591 (41.5)	9394 (42.6)	38 833 (41.1)
Primary school	2638 (7.8)	495 (6.1)	2328 (7.7)	1907 (8.6)	7368 (7.8)
Missing	331 (1.0)	76 (0.9)	191 (0.6)	218 (1.0)	816 (0.9)
Singleton pregnancy					
Yes	33 677 (99.0)	7963 (98.5)	29 220 (96.3)	21 011 (95.3)	91 871 (97.2)
No	353 (1.0)	119 (1.5)	1115 (3.7)	1040 (4.7)	2627 (2.8)
Gestational age at birth					
From week 37+0	32 640 (95.9)	7835 (96.9)	29 528 (97.3)	18 977 (86.1)	88 980 (94.2)
Before gestational week 37+0	1379 (4.1)	243 (3.0)	800 (2.6)	3062 (13.9)	5484 (5.8)
Missing	11 (0.0)	4 (0.0)	7 (0.0)	12 (0.1)	34 (0.0)
Maternal country of birth					
Sweden	28 864 (84.8)	6827 (84.5)	24 879 (82.0)	17 894 (81.1)	78 464 (83.0)
Europe	2060 (6.1)	428 (5.3)	1961 (6.5)	1293 (5.9)	5742 (6.1)
Other	3104 (9.1)	827 (10.2)	3492 (11.5)	2861 (13.0)	10 284 (10.9)
Missing	2 (0.0)	0 (0.0)	3 (0.0)	3 (0.0)	8 (0.0)

Continued

Table 1 Continued

	Spontaneous vaginal birth	Vacuum/forceps	Elective CS	Emergency CS	Total
N (%)	34 030 (36.0)	8082 (8.6)	30 335 (32.1)	22 051 (23.3)	94 498 (100.0)

Socioeconomic status=disposable income per consumption unit.
No missing data on maternal age or singleton pregnancy.
BMI, Body mass index; CS, caesarean section; ICD-10, International Classification for Diseases 10th revision; SD, standard deviation.

sensitivity analysis was performed in the same way as the main analysis.

Patient and public involvement

Neither patients nor the public were involved in the study design.

RESULTS

During 1999–2015, the total number of babies born in Sweden was 1 774 983, of which 94 498 were born as second children to women who had a first birth by CS, where both births occurred in Sweden and information about elective or emergency CS was present. Of these children, 45% were born vaginally and 55% by CS, delineated further as 36% spontaneous vaginal birth, almost 9% instrumental vaginal birth, 23% emergency CS and 32% elective CS. Mode of birth during the study years is shown in figure 2.

Table 2 Range of diagnose codes for child outcome variables

Developmental problems (ICD-10 codes F80-F89)	
F80	Specific developmental disorders of speech and language
F81	Specific developmental disorders of scholastic skills
F82	Specific developmental disorder of motor function
F83	Mixed specific developmental disorders
F84	Pervasive developmental disorders
F88	Other disorders of psychological development
F89	Unspecified disorder of psychological development
Asthma (ICD-10 codes J40-J47)	
J40	Bronchitis, not specified as acute or chronic
J41	Simple and mucopurulent chronic bronchitis
J42	Unspecified chronic bronchitis
J43	Emphysema
J44	Other chronic obstructive pulmonary disease
J45	Asthma
J46	Severe asthma
J47	Bronchiectasis
Allergy (ICD-10 code T78)	
T78	Allergy

ICD-10, International Classification for Diseases 10th revision.

The rate of problems in the total study population was 1.1% for developmental problems, 12% for asthma, 1% for severe allergy and 32% for hospital care over the years (all diagnoses and timing), and there were 340 cases of death (0.36%) for any reason within the follow-up time (table 3). Main causes of death are shown in figure 3.

Maternal conditions we controlled for were smoking (5.6%), diabetes (1.5%), BMI ≥30 (15.0%), diagnosis of mental illness (1.2%), pre-eclampsia (3.5%), level of education, socioeconomic status, mother's country of birth, not having a singleton pregnancy and prematurity, defined as birth before 37 completed weeks of pregnancy (5.8%) of all births in the study population. The mean age of mothers giving birth to their second child was almost 32 years (SD 4.6). Details are shown in table 1.

RR for developmental problems, asthma and allergy was increased after elective and emergency repeat CS but not after instrumental vaginal birth compared with spontaneous vaginal birth. The need for hospital care within 5 years was increased in all other birth modes compared with spontaneous vaginal birth. Risk of death within 5 years increased after instrumental vaginal birth and emergency repeat CS but not after elective repeat CS compared with spontaneous vaginal birth (table 4).

The sensitivity analysis, which was limited to include 74 986 children who were born between 1999 and 2012, had similar proportions of each mode of birth (online supplemental tables S2,S3) and demonstrated similar results as the main analysis (online supplemental table S4).

DISCUSSION

The results of the present study showed increased risks for developmental problems, asthma, allergy, hospital stay and death within 5 years after emergency CS compared with spontaneous vaginal birth for children born to women who had a CS first birth. Elective CS for the second child after a previous CS first birth was associated with increased risks for developmental problems, asthma, allergy and hospital stay within 5 years, compared with spontaneous vaginal birth.

We found that developmental problems were increased after elective and emergency CS but not after instrumental vaginal birth, compared with spontaneous vaginal birth. To our knowledge, no previous study has shown an increased risk of documented developmental problems (ICD-10 codes F80-F89) after both elective and emergency

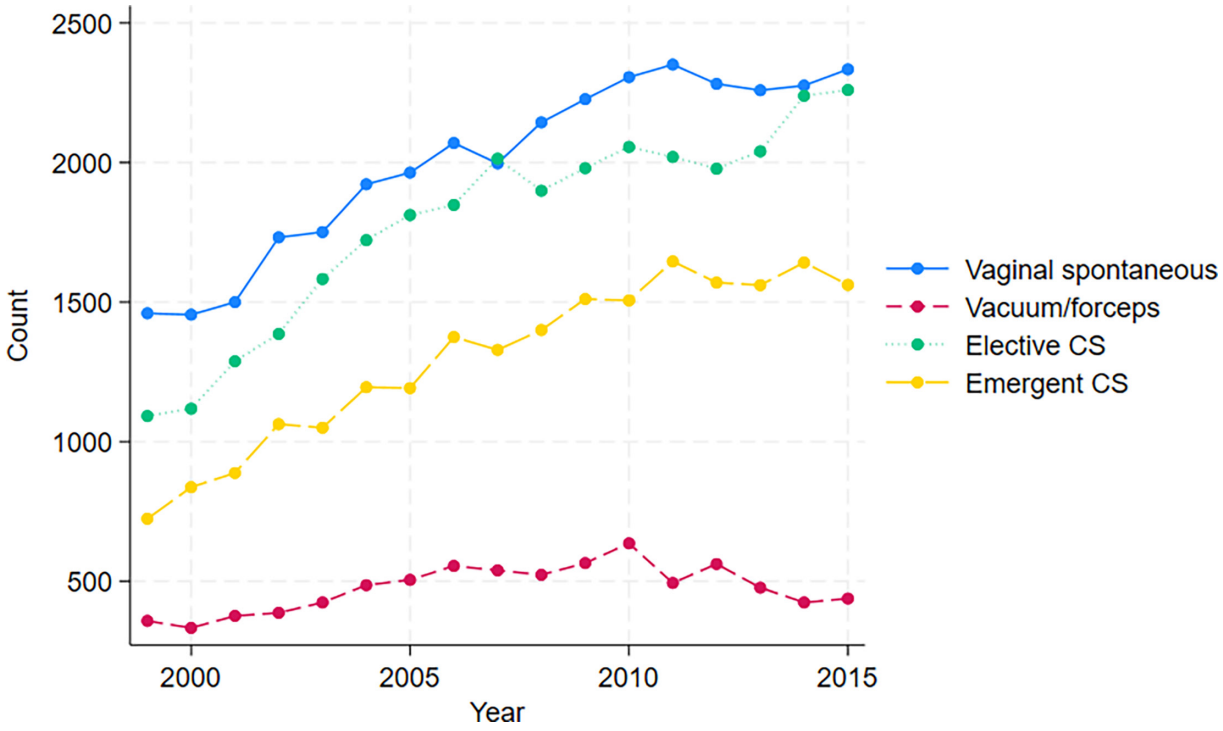

Figure 2 Mode of birth in the study population over the years 1999–2015. CS, caesarean section.

CS in children born after a first CS. Instead, earlier studies have shown similarity in development scores at 12 months[18] or little evidence of association between educational problems and planned mode of birth.[21] When it comes to emergency CS, learning problems in children have been shown,[19] and similarly increased risks of autism and ADHD disorders after all CS, but not after planned CS.[17] Studying second-born children after previous CS, Black *et al* (2016) found no increased risk of hospital care due to asthma, learning disability and death after planned CS, but found increased risk after an unplanned CS. They also showed an increased risk of learning disabilities and death at 5 years of age following unplanned repeat CS compared with VBAC.[19]

Increased risk of asthma after repeat CS is consistent with findings from earlier studies,[10–13 26] including a systematic review and meta-analysis,[10] which demonstrated increased risk for asthma after both elective and emergency repeat CS. On the contrary, a recent case-control study did not find an association between CS and increased risk of hospital care due to asthma after 7 years of age.[27]

Risk for severe allergy, specifically expressed in our data with ICD-10 code T78 including anaphylactic reactions, was increased after both elective and emergency CS compared with vaginal births (spontaneous vaginal and instrumental vaginal), corroborating earlier research on the association between CS and allergy. The relationship

Table 3 Child outcomes up to 5 years versus mode of birth in the study population

Child outcome	Spontaneous vaginal birth	Vacuum/forceps	Elective CS	Emergency CS	Total
N (%)	**34 030 (36.0)**	**8082 (8.6)**	**30 335 (32.1)**	**22 051 (23.3)**	**94 498 (100.0)**
Developmental problems (F80-F89, ICD-10 codes)	290 (0.9)	78 (1.0)	349 (1.2)	291 (1.3)	1008 (1.1)
Asthma (J40-J47, ICD-10 codes)	3573 (10.5)	858 (10.6)	4039 (13.3)	2955 (13.4)	11 425 (12.1)
Allergy (T78, ICD-10 code)	312 (0.9)	87 (1.1)	351 (1.2)	260 (1.2)	1010 (1.1)
Neonatal care/hospital care	9497 (27.9)	2512 (31.1)	9560 (31.5)	8636 (39.2)	30 205 (32.0)
Death	74 (0.22)	27 (0.33)	63 (0.21)	176 (0.80)	340 (0.36)

CS, caesarean section; ICD-10, International Classification for Diseases 10th revision.

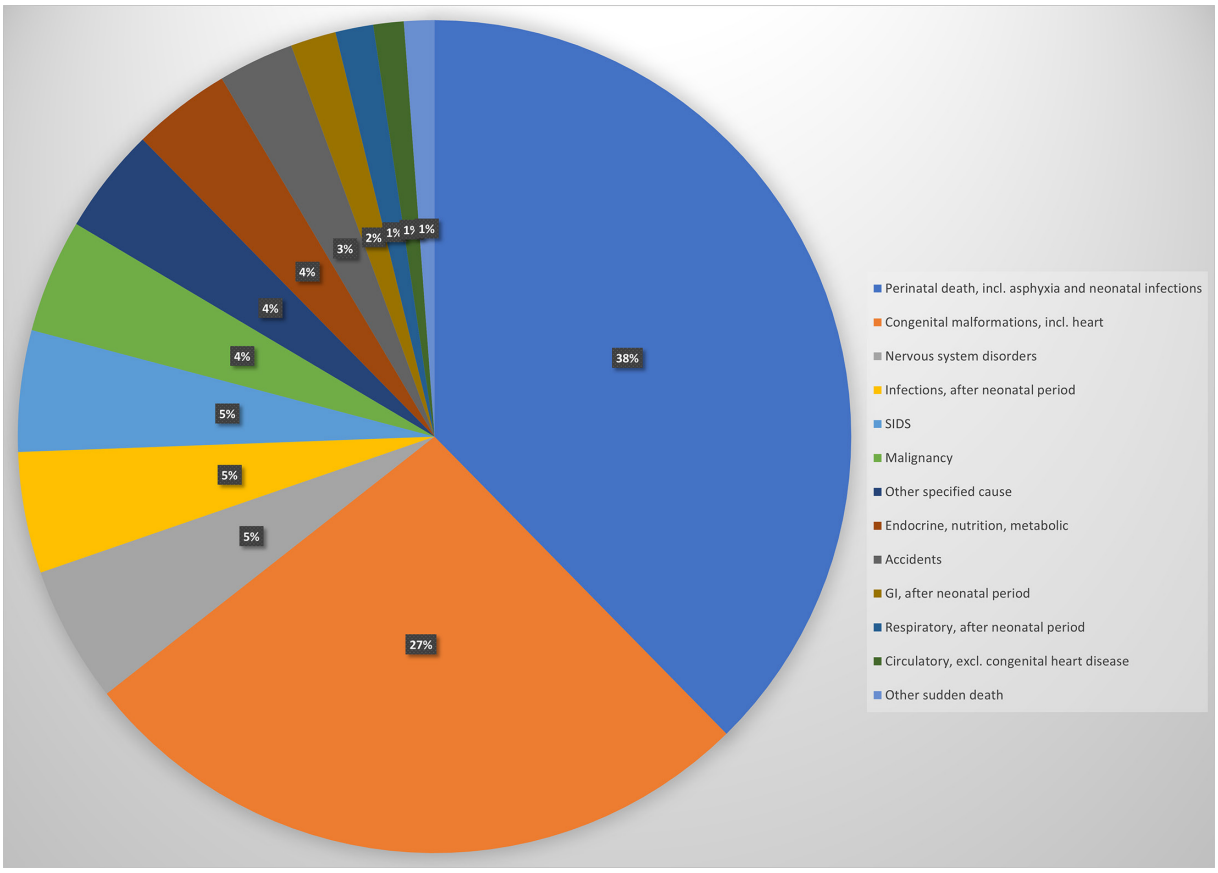

Figure 3 Main cause of death, n=340. GI, gastrointestinal; SIDS, sudden infant death syndrome.

between CS and allergy disorders is considered to be explained by the hygiene hypothesis[8] and significantly lower intestinal microbiota diversity in children born after CS.[9]

The risk of hospital care was increased for all birth modes compared with vaginal birth. Black *et al* also showed an increased risk of hospital stay due to asthma for CS birth compared with vaginal birth, but not for other diseases.[19] Furthermore, a large Danish population study of 2½ million births showed an increased risk of hospitalisation due to chronic inflammatory diseases after CS compared with spontaneous vaginal birth.[14]

Similar to earlier findings with an increased risk of death in children born after an earlier CS,[28] we found an increased risk of death in children born after an emergency CS and after instrumental vaginal birth, but not after elective CS, compared with spontaneous vaginal birth in the study population.

An awareness of the possible risk for confounding by indication must be considered in the findings of this study with regard to the associated increased risks for developmental problems, asthma, allergy and hospital stay within 5 years in the study cohort. For example, several previous studies have demonstrated an association between being born by CS and childhood diabetes mellitus type 1.[15 19] However, when accounting for available confounding factors related to both CS and risk of childhood diabetes, a recent Swedish study found that CS had no influence on the risk of type 1 diabetes during childhood or adolescence.[29] In the present study, we adjusted for maternal factors like age, smoking, diabetes, obesity, psychological/mental disorder, pre-eclampsia, education, income, having a singleton pregnancy, mother's country of birth and neonatal prematurity. Still, we cannot fully rule out the possibility of a relationship between indications for elective CS and the outcomes of this study.

We have previously, in a short-term outcome study on the same population, shown that spontaneous vaginal birth after previous CS was related to a lower risk of a combined outcome of asphyxia and/or respiratory distress when compared with any other mode of birth.[22] Our overall results indicate that decisions to perform CS (both emergency and planned) should be carefully considered before the procedure and weighed against risks of consequences for the child's health, not only in the short term but also in the long-term perspective, where decisions about CS may have consequences for the child's future health. Our results of the previous[22] and the present study support the idea that VBAC is not only safe but should be the preferred mode of birth for optimising both short-term and long-term outcomes in children up to 5 years of age.

Strengths and limitations

A main limitation of the study is the risk of possible residual confounding, due to the observational design,

Table 4 Child outcomes up to 5 years of age associated with mode of birth in women who had a CS first birth

Outcome		Unadjusted RR (95% CI)	Adjusted RR (95% CI)	P-value adjusted RR
Developmental problems (F80-F89, ICD-10 codes)	Vaginal spontaneous	Reference	Reference	
	Vacuum/forceps	1.133 (0.882, 1.454)	1.145 (0.891, 1.470)	0.290
	Elective CS	1.350 (1.155, 1.578)	1.320 (1.126, 1.547)	0.001
	Emergency CS	1.549 (1.316, 1.822)	1.383 (1.168, 1.636)	<0.001
Asthma (J40-J47, ICD-10 codes)	Vaginal spontaneous	Reference	Reference	
	Vacuum/forceps	1.011 (0.939, 1.089)	1.047 (0.972, 1.128)	0.227
	Elective CS	1.268 (1.212, 1.327)	1.323 (1.264, 1.385)	<0.001
	Emergency CS	1.276 (1.216, 1.340)	1.217 (1.157, 1.280)	<0.001
Allergy (T78, ICD-10 code)	Vaginal spontaneous	Reference	Reference	
	Vacuum/forceps	1.174 (0.926, 1.489)	1.161 (0.915, 1.473)	0.219
	Elective CS	1.262 (1.084, 1.470)	1.238 (1.059, 1.446)	0.007
	Emergency CS	1.286 (1.091, 1.516)	1.302 (1.100, 1.542)	0.002
Hospital care within 5 years	Vaginal spontaneous	Reference	Reference	
	Vacuum/forceps	1.114 (1.066, 1.164)	1.140 (1.091, 1.191)	<0.001
	Elective CS	1.129 (1.098, 1.162)	1.154 (1.121, 1.188)	<0.001
	Emergency CS	1.403 (1.363, 1.445)	1.240 (1.203, 1.279)	<0.001
Death within 5 years	Vaginal spontaneous	Reference	Reference	
	Vacuum/forceps	1.536 (0.989, 2.387)	1.727 (1.110, 2.687)	0.015
	Elective CS	0.955 (0.683, 1.336)	1.021 (0.726, 1.436)	0.906
	Emergency CS	3.670 (2.798, 4.816)	2.009 (1.510, 2.675)	<0.001

Relative risk (RR) was obtained using unadjusted and adjusted Poisson regression models, with unadjusted and adjusted results presented together with the p value of the adjusted model.
Adjusted RR: adjustments were made for mother's age, maternal smoking status at the beginning of pregnancy, maternal diabetes (self-reported to midwife), maternal obesity (height and weight measured at the beginning of pregnancy), pre-eclampsia (diagnosis codes at birth), maternal mental illness (diagnosis codes at birth), maternal education level (before birth), maternal socioeconomic status (disposable income per consumption unit in the family before birth), neonatal prematurity (gestational age up to week 36+6), being a singleton pregnancy or not and maternal country of birth.
CS, caesarean section; ICD-10, International Classification for Diseases 10th revision.

affecting the measured outcomes. However, a range of possible and known covariates were taken into consideration and used in the analyses. Missing values on used covariates and outcome variables are also a possible limitation, but missing data were also accounted for in the adjusted analyses. Additionally, relying on secondary-care data means that individuals with minor symptoms may not be identified in diagnoses from secondary care and thus not recognised in our study. However, this kind of underdiagnosis would equally occur regardless of mode of birth and thus not pose a large influence on our results. Limitations also include the limited follow-up time until 5 years of age.

Strengths of the present study include the large nationwide population cohort and the use of high-quality national registers from which to draw data and the ability to collect outcome data for up to 5 years, with few missing values. All children born in a second parity after a first CS, where both births occurred in Sweden, were included, without exclusions and followed up to 5 years. Only a small proportion of mothers (1.1%) had migrated in December 2015, meaning that we have reliable outcome data on a vast majority of the study population. Furthermore, as there was an obvious risk for confounding factors related to the indications for CS, it was a strength that the study adjusted data for maternal age, smoking, diabetes, obesity, psychological/mental disorder, pre-eclampsia, education, socioeconomic status, having a singleton pregnancy, mother's country of birth and premature birth in order to minimise the risk for confounding factors influencing the results.

One common limitation of a register-based study is that researchers are limited to the data available to them. In this study, the National Patient Register had data to the 2017-year end and Cause-of-Death Register to the 2018-year end. This meant that children who were born after

2012 had not reached 5 years of age by 2015; the study's end period. To mitigate the issue, a sensitivity analysis was performed to include children who had reached 5 years of age, which was a considerable proportion of the full study population (n=74 986 of 94 498; 79.4%). Reassuringly, the results of the overall and sensitivity analyses were similar. This implies that the study results are robust, and the inclusion of follow-up periods of 2–4 years for a proportion of included children (approx. 20%) did not pose substantial bias.

CONCLUSION

Any repeat CS compared with spontaneous vaginal birth for the second child born after a previous first CS was related to increased risks for developmental problems, asthma, allergy and hospital stay within 5 years. Furthermore, emergency repeat CS was associated with an increased risk fordeath. The results of the present study support the recommendation for VBAC as the preferred mode of birth after a CS first birth.

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REFERENCES

1 Betran AP, Ye J, Moller A-B, *et al*. Trends and projections of caesarean section rates: global and regional estimates. *BMJ Glob Health* 2021;6:e005671.
2 Souza JP, Gülmezoglu A, Lumbiganon P, *et al*. Caesarean section without medical indications is associated with an increased risk of adverse short-term maternal outcomes: the 2004-2008 WHO Global Survey on Maternal and Perinatal Health. *BMC Med* 2010;8:71.
3 Dumont A, de Loenzien M, Nhu HMQ, *et al*. Caesarean section or vaginal delivery for low-risk pregnancy? Helping women make an informed choice in low- and middle-income countries. *PLOS Glob Public Health* 2022;2:e0001264.
4 Villar J, Valladares E, Wojdyla D, *et al*. Caesarean delivery rates and pregnancy outcomes: the 2005 WHO global survey on maternal and perinatal health in Latin America. *The Lancet* 2006;367:1819–29.
5 Laurita Longo V, Odjidja EN, Beia TK, *et al*. "An unnecessary cut?" multilevel health systems analysis of drivers of caesarean sections rates in Italy: a systematic review. *BMC Pregnancy Childbirth* 2020;20:770.
6 Landon MB, Hauth JC, Leveno KJ, *et al*. Maternal and perinatal outcomes associated with a trial of labor after prior cesarean delivery. *N Engl J Med* 2004;351:2581–9.
7 Ramachandrappa A, Jain L. Elective cesarean section: its impact on neonatal respiratory outcome. *Clin Perinatol* 2008;35:vii:373–93, .
8 Björkstén B, Naaber P, Sepp E, *et al*. The intestinal microflora in allergic Estonian and Swedish 2-year-old children. *Clin Exp Allergy* 1999;29:342–6.
9 Jakobsson HE, Abrahamsson TR, Jenmalm MC, *et al*. Decreased gut microbiota diversity, delayed Bacteroidetes colonisation and reduced Th1 responses in infants delivered by caesarean section. *Gut* 2014;63:559–66.
10 Darabi B, Rahmati S, HafeziAhmadi MR, *et al*. The association between caesarean section and childhood asthma: an updated systematic review and meta-analysis. *Allergy Asthma Clin Immunol* 2019;15:62.
11 Keag OE, Norman JE, Stock SJ. Long-term risks and benefits associated with cesarean delivery for mother, baby, and subsequent pregnancies: Systematic review and meta-analysis. *PLoS Med* 2018;15:e1002494.
12 Håkansson S, Källén K. Caesarean section increases the risk of hospital care in childhood for asthma and gastroenteritis. *Clin Exp Allergy* 2003;33:757–64.
13 Magnus MC, Håberg SE, Stigum H, *et al*. Delivery by Cesarean section and early childhood respiratory symptoms and disorders: the Norwegian mother and child cohort study. *Am J Epidemiol* 2011;174:1275–85.
14 Andersen V, Möller S, Jensen PB, *et al*. Caesarean Delivery and Risk of Chronic Inflammatory Diseases (Inflammatory Bowel Disease, Rheumatoid Arthritis, Coeliac Disease, and Diabetes Mellitus): A Population Based Registry Study of 2,699,479 Births in Denmark During 1973-2016. *Clin Epidemiol* 2020;12:287–93.
15 Cardwell CR, Stene LC, Joner G, *et al*. Caesarean section is associated with an increased risk of childhood-onset type 1 diabetes mellitus: a meta-analysis of observational studies. *Diabetologia* 2008;51:726–35.
16 Zheng X, Li R, Wang L, *et al*. The association of cesarean section with overweight and neurodevelopment of Chinese children aged 1-5 months. *Front Pediatr* 2022;10:940422.
17 Zhang T, Sidorchuk A, Sevilla-Cermeño L, *et al*. Association of Cesarean Delivery With Risk of Neurodevelopmental and Psychiatric Disorders in the Offspring: A Systematic Review and Meta-analysis. *JAMA Netw Open* 2019;2:e1910236.

18 Zaigham M, Hellström-Westas L, Domellöf M, *et al*. Prelabour caesarean section and neurodevelopmental outcome at 4 and 12 months of age: an observational study. *BMC Pregnancy Childbirth* 2020;20:564.
19 Black M, Bhattacharya S, Philip S, *et al*. Planned Repeat Cesarean Section at Term and Adverse Childhood Health Outcomes: A Record-Linkage Study. *PLoS Med* 2016;13:e1001973.
20 Wolf HT, Weber T, Schmidt S, *et al*. Mode of delivery and adverse short- and long-term outcomes in vertex-presenting very preterm born infants: a European population-based prospective cohort study. *J Perinat Med* 2021;49:923–31.
21 Fitzpatrick KE, Kurinczuk JJ, Quigley MA. Planned mode of birth after previous caesarean section and special educational needs in childhood: a population-based record linkage cohort study. *BJOG* 2021;128:2158–68.
22 Dencker A, Lyckestam Thelin I, Smith V, *et al*. Neonatal outcomes associated with mode of subsequent birth after a previous caesarean section in a first pregnancy: a Swedish population-based register study between 1999 and 2015. *BMJ Paediatr Open* 2022;6:e001519.
23 Cnattingius S, Källén K, Sandström A, *et al*. The Swedish medical birth register during five decades: documentation of the content and quality of the register. *Eur J Epidemiol* 2023;38:109–20.
24 Ludvigsson JF, Andersson E, Ekbom A, *et al*. External review and validation of the Swedish national inpatient register. *BMC Public Health* 2011;11:450.
25 Brooke HL, Talbäck M, Hörnblad J, *et al*. The Swedish cause of death register. *Eur J Epidemiol* 2017;32:765–73.
26 Black M, Bhattacharya S, Philip S, *et al*. Planned Cesarean Delivery at Term and Adverse Outcomes in Childhood Health. *JAMA* 2015;314:2271–9.
27 Rodríguez Calleja J, Jiménez Hernández EM, Macías Panedas A, *et al*. Study on the Association between Cesarean Section Birth and Asthma Risk in the Pediatric Population of the Health Area of Palencia between 1993 and 2020. *Allergol Immunopathol* 2024;52:68–72.
28 Carlsson Wallin M, Ekström P, Marsál K, *et al*. Apgar score and perinatal death after one previous caesarean delivery. *BJOG* 2010;117:1088–97.
29 Samuelsson U, Lindell N, Bladh M, *et al*. Caesarean section per se does not increase the risk of offspring developing type 1 diabetes: a Swedish population-based study. *Diabetologia* 2015;58:2517–24.