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Association of Severe Maternal Morbidity With Subsequent Birth

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IMPORTANCE Women who experience severe maternal morbidity (SMM) might have lasting health issues, and the association of SMM with the probability of future reproductive intentions is unknown.

OBJECTIVE To examine the association between SMM in a first birth and the probability of a subsequent birth.

DESIGN, SETTING, AND PARTICIPANTS Retrospective, population-based cohort study conducted among 1 046 974 women in Sweden who had their first birth between 1999 and 2021.

EXPOSURE Overall SMM and SMM subtypes were identified among all deliveries at 22 weeks of gestation or later (including complications within 42 days of delivery) from the Swedish Medical Birth Register and National Patient Register.

MAIN OUTCOMES AND MEASURES All women with a recorded first delivery were followed up from 43 days postpartum until the first day of the last menstrual period of the second pregnancy that resulted in a birth (stillbirth or live birth) or until death, emigration, or end of follow-up on December 31, 2021. Multivariable Cox proportional hazards regression was used to estimate associations between SMM and time to subsequent birth with adjusted hazard ratios (aHRs). Sibling analysis was performed to evaluate potential genetic and familial confounding.

RESULTS A total of 36 790 women (3.5%) experienced an SMM condition in their first birth. Women with any SMM had a lower incidence rate of subsequent birth compared with those without SMM in their first delivery (136.6 vs 182.4 per 1000 person-years), with an aHR of 0.88 (95% CI, 0.87-0.89). The probability of subsequent birth was substantially lower among women with severe uterine rupture (aHR, 0.48; 95% CI, 0.27-0.85), cardiac complications (aHR, 0.49; 95% CI, 0.41-0.58), cerebrovascular accident (aHR, 0.60; 95% CI, 0.50-0.73), and severe mental health conditions (aHR, 0.48; 95% CI, 0.44-0.53) in their first birth. The associations were not influenced by familial confounding as indicated by sibling analyses.

CONCLUSIONS AND RELEVANCE Our findings suggest that women who experience SMM in their first birth are less likely to have a subsequent birth. Adequate reproductive counseling and enhancing antenatal care are crucial for women with a history of SMM.

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Editorial page 122

Multimedia

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Severe maternal morbidity (SMM) is a sentinel event and is defined using one of several composites that index life-threatening events occurring during pregnancy, delivery, and up to 42 days postpartum.[1-3] Rates of SMM have been steadily increasing in several countries, such as the United States and Canada.[3-5] In Sweden, from 1999 to 2019, the composite SMM rate was 270.2 per 10 000 deliveries, and different types of SMM, such as pulmonary and obstetric embolism, disseminated intravascular coagulation and shock, acute kidney failure, cardiac complications, sepsis, and assisted ventilation, showed significant increases during this period.[6]

Women may experience persistent health issues after SMM, including reproductive challenges, even after their initial complication resolves.[7] These long-term consequences may include loss of reproductive ability as a result of lifesaving procedures such as hysterectomy, as well as decreased fertility, leading to physical and emotional consequences.[7-11] Severe obstetric complications and pregnancy-related interventions such as blood transfusions have been shown to variously influence the probability of future childbearing, although associations differ between populations and outcomes.[12-14]

A few small case-control studies have found that women who experience SMM at the time of their first birth are at an increased risk of general and reproductive health problems after pregnancy.[7,9,15] Only 1 cohort study has investigated the association between SMM in the first pregnancy and the risk of

having an additional birth; that study found a 17% reduced likelihood of subsequent birth among these women. However, this study had methodological constraints, such as lack of accounting for population loss due to relocation out of state and the competing risk of death.[12] Furthermore, additional sources of confounding between initial SMM and later births may exist (ie, SMM could be due to genetic factors), and failure to control for this could affect the association. We are unaware of any studies that have explored this possibility, eg, using sibling-controlled analyses to provide insight into the role of shared familial factors in the association of SMM and the probability of a subsequent birth.

In this nationwide cohort study in Sweden, we aimed to quantify the association between experiencing SMM in the first birth and probability and timing of a subsequent birth. We further used competing risk analysis to account for the competing risk of death and sibling analysis to assess familial confounding.

Key Points

Question What is the association of severe maternal morbidity (SMM) during a first birth with the probability of having a subsequent birth?

Findings In this nationwide population cohort study in Sweden, women with any SMM had a significantly lower incidence rate of subsequent birth compared with those without SMM in their first delivery (136.6 vs 182.4 per 1000 person-years). The associations were not influenced by familial confounding as indicated by sibling analyses.

Meaning Women who experience SMM in their first birth are less likely to have a subsequent birth. Adequate reproductive counseling and enhancing antenatal care are crucial for these women.

Methods

Study Design

This was a population-based retrospective cohort study in Sweden including deliveries between 1999 and 2021. Information from different data sources were linked using personal unique national registration identifiers. All residents are assigned a unique personal identification number at birth or immigration, which can be used to link information from repeated pregnancies in the different national registers.[16] Acquisition of informed consent was waived due to the register-based nature of the study and deidentification of the participants. This study was approved by the Ethics Review Authority in Sweden (approval number 2023-00331-02).

Data Sources

We cross-linked the Swedish Medical Birth Register (MBR) with the nationwide National Patient Register (NPR) and the population, multigenerational, and education registers. The MBR contains information for antenatal, obstetric, and neonatal care from more than 98% of the births (stillbirths and live births after 22 weeks of gestation) in Sweden.[17,18] The NPR holds information for all inpatient care since 1987 and additionally for all specialist outpatient care since 2001.[19] Diagnoses in MBR and NPR are coded according to the Swedish *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* (*ICD-10*) from 1997 onward.[20] The Total Population Register and the Register on Participation in Education were used to extract demographic information.[21] The Swedish Multi-Generation Register connects every person born in Sweden since 1932 and those ever registered in the country since 1961 with their biological parents, which allowed for identification of full siblings.[22]

Study Cohort

Between January 1, 1999, and December 31, 2021, there were 2 436 973 singleton and multiple births recorded in the MBR (excluding women with a missing identification number). We restricted our cohort to women with their first birth recorded during the study period, and we excluded women with missing maternal age, missing infant gestational age or sex, or hysterectomy during the first delivery. We also excluded women with less than 43 days of follow-up time after their first delivery. The final analytical sample comprised 1 046 974 women with a recorded first delivery (**Figure 1**).

Exposure

The main exposure was any SMM event during the first birth, identified based on diagnostic and procedure codes in hospital records between 22 weeks of gestation and 42 days postdelivery. We defined SMM as a composite event consisting of the following 14 distinct SMM types: (1) severe preeclampsia, HELLP (hemolysis, elevated liver enzymes, and low platelet count) syndrome, eclampsia; (2) severe hemorrhage; (3) surgical complications; (4) hysterectomy; (5) sepsis; (6) pulmonary and obstetric embolism, disseminated intravascular coagulation, shock; (7) cardiac complications; (8) acute kidney failure, dialysis; (9) severe uterine rupture; (10) cerebrovascular accident; (11) complications of anesthesia during pregnancy, labor and delivery, or puerperium; (12) severe mental health conditions; (13) assisted ventilation; and (14) other types (including sickle cell anemia with crisis, acute and subacute liver failure, acute respiratory distress syndrome, and status epilepticus). We used a comprehensive and validated definition of SMM that is used for maternal health surveillance in Sweden (see eTable 1 in Supplement 1 for specific codes). The identification process of SMM events and subtypes has been described in detail elsewhere.[6]

We analyzed SMM both as a composite outcome and separately for each type. The SMM conditions were not mutually exclusive; for instance, a woman experiencing postpartum hemorrhage with transfusion and septicemia during labor would be counted in both the severe hemorrhage and sepsis categories but would be considered as a single case of SMM overall.

Outcome

The primary outcome was time to subsequent birth (ie, live birth or stillbirth, defined as fetal death at or after 22 weeks of

gestation). All subsequent births were based on live birth or stillbirth recorded in the MBR from 1999 through 2021. Information on stillbirths was available from 28 weeks of gestation onward from 1999 to July 1, 2008, and thereafter from 22 weeks of gestation. To identify subsequent births, we followed up with each woman from 43 days postpartum after the first birth until the best estimation of the first day of the last menstrual period of the second pregnancy that resulted in a birth (outcome) during the study period, or death, emigration, or the study end date of December 31, 2021, whichever came first. The best estimator was determined hierarchically, first by ultrasound date, then by last menstrual period, and finally by clinical evaluation in neonatal records.[18]

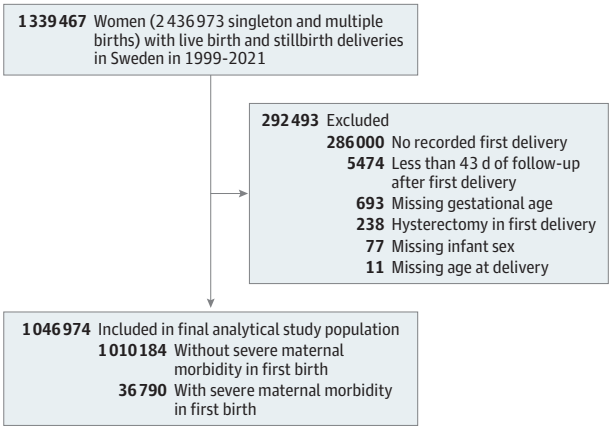
Covariates

We considered maternal pregestational and health-related characteristics from the first birth, retrieved from the MBR. Maternal characteristics included were maternal age at delivery, body mass index, education level, height, smoking, country of birth, use of assisted reproductive technology, cohabitation with a partner, multiple birth, calendar year of birth, pregestational hypertension, and pregestational diabetes. Body mass index, categorized according to the World Health Organization recommendation,[23] was calculated as weight in kilograms divided by height in meters squared, using weight measured at registration to antenatal care, wearing light indoor clothing, and self-reported height. Information on cohabitation with a partner was obtained at the first antenatal visit. Women who reported daily smoking at the first antenatal visit and/or at 30 to 32 weeks of gestation were classified as smoking. We adjusted our models based on preselected factors that are shown to be associated with SMM and subsequent birth.[24,25] To avoid the risk of an overadjustment bias, all covariates included in the model were measured at the first birth.

Statistical Analyses

We compared baseline clinical and demographic characteristics among women with presence and absence of SMM in their first recorded delivery. For the probability of a subsequent birth, we included all women with or without a second birth. This analysis used a Cox proportional hazards regression model estimating hazard ratios (HRs) and corresponding 95% CIs for the probability of or time to subsequent birth. We furthermore calculated rates of subsequent births per 1000 person-years for those with and without SMM during their first birth and the unadjusted rate differences and 95% CIs between the 2 groups. Finally, we plotted the cumulative incidence rates of subsequent birth by exposure status at the first birth. We evaluated the proportional hazard assumption using the Schoenfeld residuals method and found no strong evidence of violation for either the exposure or its subtypes. In the multivariable analyses, estimates were adjusted for maternal age, educational level, maternal height, body mass index, multiple birth, smoking, use of assisted reproductive technology, cohabitation with a partner, country of birth, calendar year of birth, and pregestational diabetes and hypertension prior to the first delivery.

Figure 1. Development of the Study Cohort



Sibling Analyses

To account for potential genetic and familial confounding, outcomes of SMM-exposed women were compared with those of their non-SMM-exposed full sisters using stratified Cox proportional hazards models with a separate stratum for each sibling set. By design, this method controls potential familial confounders that are shared by full siblings, including approximately 50% of their genetic makeup, and controls for unmeasured shared environmental factors, such as socioeconomic status.[26] With the stratified Cox models, we allowed for different baseline hazards for each stratum. In comparing specific SMM types in exposed women, the control group consisted of their sisters unexposed to any SMM.

Sensitivity Analyses

We performed several sensitivity analyses. First, to avoid any right censoring effect (ie, women who gave birth in the last 4 years had less time to become pregnant again), we excluded women who had their first birth after December 31, 2017, so that each woman had sufficient follow-up time to have a subsequent birth. Second, in an effort to isolate any potential effect of SMM in the first birth on future fertility from trauma due to preterm birth or fetal loss, in the sensitivity analyses, we stratified first births by those with adverse neonatal outcomes (defined as stillbirths, births with major malformations, or births before 32 weeks of gestation) and those without adverse outcomes. Third, we further considered death as a competing event in assessing the probability of having a subsequent birth, since previous research has shown that women who have experienced SMM have an accelerated risk of mortality.[7,27] We used competing risk regression with the Fine-Gray method to estimate the subdistribution of HRs expressing the association between SMM in the first birth and the probability of a subsequent birth after accounting for the competing risk of mortality. Fourth, we stratified our analysis by singleton and multiple births, considering that women with multifetal pregnancies may complete their desired family size after the first pregnancy, reducing the likelihood of a subsequent one. To further visualize temporal patterns between SMM

and probability of subsequent birth, we estimated time-dependent effects on subsequent birth with flexible parametric survival models, with 2 degrees of freedom for the baseline hazard and 2 degrees of freedom for the time-varying effect of SMM case/comparator. Those models allow the HRs to change continuously over follow-up time. Finally, given that older women have a higher risk of a severe maternal event and a lower rate of subsequent births, we restricted our analysis to women younger than 35 years at the time of their first birth.

Results

Demographic and Clinical Characteristics

Among 1 046 974 women included in the study, 36 790 (3.5%) experienced SMM at first birth. Women with SMM were more likely to be older, be shorter, have higher body mass index, and have pregestational hypertension and diabetes and use of assisted reproductive technology compared with women without SMM in their first birth. Additionally, they had a higher frequency of multifetal pregnancy (twins or higher order), induction of labor or cesarean delivery, and preterm birth (**Table**).

SMM and Subsequent Birth

Unadjusted cumulative incidence curves showed consistently lower cumulative hazard of subsequent birth among women who had SMM at first birth compared with those who did not throughout the entire duration of follow-up (**Figure 2**). Women with composite SMM had a lower incidence rate of subsequent birth compared with those without SMM in their first delivery (136.6 vs 182.4 per 1000 person-years) (**Figure 3**). After adjusting for maternal characteristics, SMM in the first birth was associated with a lower rate of having a subsequent birth over the follow-up period (adjusted HR [aHR], 0.88; 95% CI, 0.87-0.89) (Figure 3).

A lower rate of subsequence birth was observed regardless of the type of SMM in the first delivery (Figure 3), but the rate reduction was most pronounced if the initial morbidity was a cardiac complication (aHR, 0.49; 95% CI, 0.41-0.58), severe uterine rupture (aHR, 0.48; 95% CI, 0.27-0.85), or severe mental health condition (aHR, 0.48; 95% CI, 0.44-0.53) (Figure 3). The adjusted rate of subsequent birth was 40% lower after a first delivery that required assisted ventilation or involved cerebrovascular accident, and was 35%, 14%, and 13% lower if the first delivery involved acute kidney failure/dialysis, severe preeclampsia/HELLP syndrome/eclampsia, or embolism/disseminated intravascular coagulation/shock, respectively (Figure 3). Sepsis and anesthesia complications in the first pregnancy were not associated with lower rate of subsequent birth.

Sibling Analyses

The subcohort used to compare the probability of subsequent birth in women with any type of SMM in their first birth (n = 9575) vs their full sisters without SMM in their first birth (n = 11 306) revealed similar associations as the population-based analysis (aHR, 0.88; 95% CI, 0.84-0.93) (**Figure 4**). Baseline clinical and demographic characteristics among sisters with SMM and without SMM in their first delivery are presented in eTable 2 in Supplement 1. Among the SMM subtypes, most associations were similar (eg, severe preeclampsia, HELLP syndrome, eclampsia, surgical complications) or even larger in magnitude (eg, cerebrovascular accident, severe mental health conditions) than those in the primary analyses. However, other results had wide confidence intervals and were not statistically significant, likely due to the smaller numbers of patients.

Sensitivity Analyses

We performed several sensitivity analyses. First, restricting our cohort to women with a first delivery from 1999 to 2017, ensuring a minimum 4-year follow-up for observing subsequent births, yielded estimates similar to the main analysis (eTable 3 in Supplement 1). Second, stratified analyses based on selected adverse neonatal outcomes experienced in the first birth showed a lower HR of subsequent birth among women who jointly experienced SMM and had an adverse neonatal outcome (stillbirth, very preterm birth, or major malformation) (aHR, 0.81; 95% CI, 0.77-0.84) compared with those with SMM but without adverse neonatal outcomes (aHR, 0.89; 95% CI, 0.88-0.91) (eTable 4 in Supplement 1). Third, Fine-Gray models, considering the competing risk of death for women without subsequent births who died during follow-up (n = 1803), showed subdistribution aHRs closely aligning with traditional Cox model estimates (eTable 5 and eFigure 1 in Supplement 1). Fourth, stratifying by singleton vs multiple births in the first delivery suggested that overall, women with singleton births were less likely to have a subsequent birth; however, these results need to be interpreted with caution because power was limited in the analyses of multiple births (eTable 6 in Supplement 1). Fifth, time-varying HRs varied consistently but remained below 1. As follow-up time increased, HRs comparing women with SMM vs without SMM suggested a reduced HR for subsequent birth (eFigure 2 in Supplement 1). Finally, restricting the analysis to women younger than 35 years did not alter the associations (eTable 7 in Supplement 1).

Discussion

In this nationwide Swedish population-based cohort study, we found that women who experienced SMM vs no SMM at the time of their first birth had a lower rate of having a subsequent birth. The lower rates were most pronounced if women had cardiac complications, severe uterine rupture, severe mental health conditions, assisted ventilation, or cerebrovascular accident at the time of the first delivery. Even when accounting for the competing risk of death, the associations remained unchanged. However, sepsis and anesthesia complications during the first birth did not show a significant association with a lower probability of subsequent birth. Sibling analyses suggested that the main associations identified in the primary analyses were not attributable to familial confounding.

Table. Baseline Clinical and Demographic Characteristics Among Individuals With and Without SMM During Their First Birth, Sweden, 1999-2021

Maternal and pregnancy characteristics	At least 1 SMM condition in first birth (n = 36 790)	No SMM condition in first birth (n = 1 010 184)
Maternal age, median (IQR), y	29 (26-33)	28 (25-32)
Maternal height, median (IQR), cm	166 (162-170) [n = 34 520]	167 (162-171) [n = 959 546]
Maternal body mass index, median (IQR)[a]	24 (21.6-27.4) [n = 33 219]	23.3 (21.3-26.2) [n = 925 046]
Country of birth, No. (%)		
Nordic[b]	29 991 (81.6)	808 139 (80.1)
Non-Nordic	6760 (18.4)	200 584 (19.9)
Cohabitation with a partner, No. (%)	31 631 (91.6)	882 067 (91.8)
Years of education, No. (%)		
≤9	2329 (6.4)	66 867 (6.7)
10-11	3175 (8.8)	81 830 (8.3)
12	9881 (27.2)	272 151 (27.4)
13-14	5435 (15.0)	149 921 (15.1)
≥15	15 458 (42.6)	422 464 (42.5)
Year of delivery, No. (%)		
1999-2005	10 315 (28.0)	274 270 (27.2)
2006-2010	8930 (24.3)	228 203 (22.6)
2011-2015	8446 (23.0)	232 417 (23.0)
2016-2021	9099 (24.7)	275 294 (27.2)
Smoking, No. (%)[c]	1939 (5.6)	68 699 (7.1)
Assisted reproductive technology, No. (%)		
In vitro fertilization or intracytoplasmic sperm injection	2561 (7.0)	48 556 (4.8)
Ovarian stimulation only	568 (1.5)	12 997 (1.3)
Birth plurality, No. (%)		
Singleton	34 953 (95.0)	996 615 (98.7)
Twins	1803 (4.9)	13 364 (1.3)
Triplets or higher order	34 (0.1)	205 (<0.1)
Gestational age at delivery, wk, No. (%)		
22-27	718 (2.0)	3591 (0.4)
28-31	1794 (4.9)	5622 (0.6)
32-36	6978 (19.0)	50 381 (5.0)
37-41	24 992 (67.9)	864 885 (85.6)
≥42	2308 (6.3)	85 705 (8.5)
Labor, No. (%)		
Spontaneous	16 684 (45.9)	783 098 (77.9)
Induced	11 366 (31.3)	158 577 (15.8)
Planned cesarean delivery	8268 (22.8)	63 129 (6.3)
Mode of delivery, No. (%)		
Noninstrumental vaginal	15 864 (43.7)	701 038 (69.8)
Elective cesarean	8268 (22.8)	63 125 (6.3)
Emergency cesarean	7129 (19.6)	117 839 (11.7)
Instrumental vaginal	5057 (13.9)	122 797 (12.2)
Pregestational hypertension, No. (%)[d]	709 (1.9)	5969 (0.6)
Diabetes, No. (%)[e]		
Gestational	660 (1.8)	13 215 (1.3)
Pregestational	519 (1.4)	4453 (0.4)

Abbreviations: *ICD-9*, *International Classification of Diseases, Ninth Revision*; *ICD-10*, *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision*; SMM, severe maternal morbidity.

[a] Calculated as weight in kilograms divided by height in meters squared.

[b] Nordic countries include Sweden, Norway, Finland, Denmark, and Iceland.

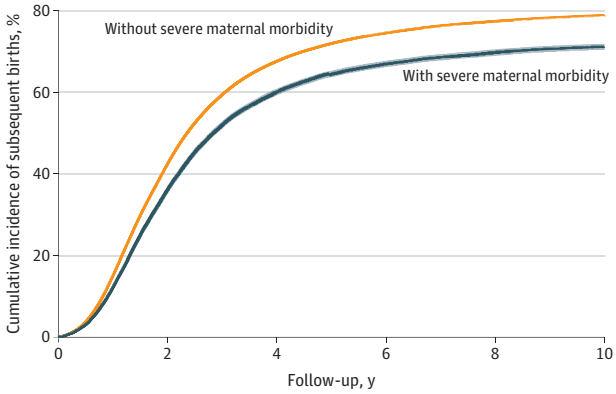
[c] Women who reported daily smoking at the first antenatal visit and/or at 30 to 32 weeks of gestation were classified as smoking.

[d] Pregestational hypertension was defined by *ICD-9* codes 401-405, 642.2, and 642.7 and *ICD-10* codes I10-I15, O10, and O11. The definition of pregestational hypertension also included self-reported information at the first antenatal visit.

[e] Gestational diabetes was defined by *ICD-9* code 648.8 and *ICD-10* code O24.4. Pregestational diabetes was defined by *ICD-9* codes 250 and 648.0 and *ICD-10* codes E10-E14 and O24.1-O24.3.

Our study confirmed previous research indicating a 17% lower adjusted rate of having a second birth among women experiencing SMM during their first delivery.[12] Cardiac complications, severe uterine rupture, severe mental health conditions, and assisted ventilation were associated with the greatest decrease in the likelihood of a second birth, while preeclampsia,

Figure 2. Kaplan-Meier Cumulative Incidence Rates of Subsequent Birth Among Women With and Without Severe Maternal Morbidity in Their First Birth



No. at risk

Without severe maternal morbidity	1 010 184	516 353	250 707	169 648	128 778	101 327
With severe maternal morbidity	36 790	21 201	11 644	8430	6683	5374

Follow-up time is truncated at 10 years. Median follow-up time for women with severe maternal morbidity was 2.37 (IQR, 1.32-5.36) years and for those without severe maternal morbidity was 2.05 (IQR, 1.17-3.97) years. Shading indicates 95% CI.

eclampsia and HELLP syndrome, and embolism slightly lowered the risk. This finding is consistent with existing literature, which suggests that women with preeclampsia had a subsequent pregnancy rate of 60% compared with 68% in those without preeclampsia.[14] It aligns with the expectation that conditions like cardiac complications, cerebrovascular accident, and assisted ventilation indicate more clinically severe cases, suggesting underlying maternal morbidity compared with labor-induced complications such as severe hemorrhage, anesthesia complications, and sepsis.[12]

In sibling analyses, the likelihood of second delivery showed robust association with overall SMM. Associations with specific SMM types such as severe preeclampsia, HELLP syndrome, eclampsia, surgical complications, cardiac complications, and severe mental health issues were similar or even stronger than in primary analyses. This implies that the reduced probability of subsequent delivery in women with SMM is independent of shared genes or environment, suggesting a direct effect of SMM on fertility or pregnancy choices. For example, due to the high recurrence rate of certain conditions, such as cardiac complications in subsequent pregnancies,[28] and the increased risk of severe morbidity and mortality among women experiencing those conditions and their offspring,[29-32] health care professionals might advise against further pregnancies. However, recommendations are typically individualized based on various factors.[30,33] Additionally, a subsequent high-risk pregnancy or birth increases the chance of the first child losing a parent, creating a major public health issue due to the negative effects of bereavement.[34,35]

Broader literature indicates that trauma during delivery may affect future reproductive desires.[7,36] A large population-based cohort study in Sweden found that women experiencing severe perineal lacerations at their first birth had slightly fewer overall births.[37] Furthermore, medical interventions like blood transfusion and cesarean delivery, often necessary for managing severe maternal conditions, are also linked to a reduced chance of subsequent births.[38-40] Other studies suggest that SMM is associated with a nonsignificant trend of having fewer children.[7] In addition, health procedures such as hysterectomy and tubal ligation can affect the fertility of affected women and increase the risk of complications in subsequent pregnancies.[7,15]

Accounting for death as a competing risk for subsequent birth yielded similar estimates, highlighting the rarity of mortality in reproductive-aged women in Sweden. Over a 22-year follow-up, only 1803 deaths occurred among those without a subsequent birth, thus indicating that the management of SMM in Sweden likely prevents this outcome. In addition, incorporating time-varying HRs did not alter the results, suggesting that women followed up for longer durations had reduced probability of a second birth. This trend aligns with the expected decline in reproductive capacity with age, particularly since women with SMM are typically older than those without SMM.[25]

In line with prior research,[12] our results showed that women with SMM who also experienced adverse neonatal outcomes (ie, stillbirth, very preterm birth, or major malformation) have a reduced likelihood of subsequent birth compared with those with SMM but without adverse neonatal outcomes. Neonatal complications are known to contribute to posttraumatic stress disorder after childbirth,[12,41] potentially explaining that these women may avoid another birth due to the added traumatic burden of adverse neonatal outcomes.

We observed a 50% lower likelihood of having a second birth among women who experience severe mental health conditions during their first birth. In the current study, we defined severe mental health conditions as acute psychosis, suicide attempts, or any primary diagnosis requiring psychiatric inpatient care within the initial 42 days postpartum. Previous research indicates that postpartum psychosis or mood disorders decrease the probability of subsequent births.[42,43] Psychosis can manifest in conditions like substance abuse, bipolar disorder, severe depression, acute stress, and schizophrenia.[44] Studies on schizophrenia, substance abuse, and bipolar disorders show lower rates of childbearing compared with the general population.[45,46] The reasons for the reduced likelihood of

Figure 3. Hazard Ratios for Subsequent Birth Among Women With SMM and Specific SMM Types at the Time of Their First Birth, Sweden, 1999-2021

SMM during first birth	Total No. of women	No. with subsequent births	Rate of subsequent births per 1000 person-years	Unadjusted rate difference per 1000 person-years (95% CI)	Crude HR (95% CI)	Adjusted HR (95% CI)[a]
No SMM (unexposed)[b]	1 010 184	694 923	182.4	[Reference]	1 [Reference]	1 [Reference]
Any SMM (primary exposure)[c]	36 790	23 051	136.6	-45.84 (-47.65 to -44.03)	0.81 (0.79 to 0.82)	0.88 (0.87 to 0.89)
Type of SMM						
Severe preeclampsia, HELLP syndrome, eclampsia	16 904	10 215	130.2	-52.22 (-54.78 to -49.66)	0.77 (0.76 to 0.79)	0.86 (0.84 to 0.88)
Severe hemorrhage	16 114	10 853	151.7	-30.69 (-33.58 to -27.81)	0.88 (0.87 to 0.90)	0.94 (0.92 to 0.96)
Surgical complications	623	378	111.2	-71.15 (-82.38 to -59.93)	0.72 (0.65 to 0.79)	0.89 (0.80 to 0.99)
Sepsis	1500	951	157.1	-25.25 (-35.24 to -15.25)	0.90 (0.84 to 0.96)	0.96 (0.90 to 1.03)
Embolism, disseminated intravascular coagulation, shock	898	516	127.7	-54.71 (-65.73 to -43.68)	0.74 (0.68 to 0.81)	0.87 (0.79 to 0.95)
Cardiac complications	508	169	56.8	-125.6 (-134.2 to -117.1)	0.36 (0.31 to 0.42)	0.49 (0.41 to 0.58)
Acute kidney failure, dialysis	166	70	83.5	-98.91 (-118.47 to -79.35)	0.49 (0.39 to 0.63)	0.65 (0.50 to 0.84)
Severe uterine rupture	32	15	69.4	-113.0 (-148.1 to -77.92)	0.50 (0.30 to 0.84)	0.48 (0.27 to 0.85)
Cerebrovascular accident	252	116	79.1	-103.3 (-117.7 to -88.86)	0.51 (0.43 to 0.61)	0.60 (0.50 to 0.73)
Anesthesia complications	138	88	120.0	-62.49 (-87.54 to -37.43)	0.78 (0.63 to 0.96)	0.93 (0.74 to 1.17)
Severe mental health conditions	1243	543	70.2	-112.2 (-118.1 to -106.3)	0.45 (0.41 to 0.49)	0.48 (0.44 to 0.53)
Assisted ventilation	130	46	91.5	-90.86 (-117.31 to -64.4)	0.45 (0.33 to 0.60)	0.57 (0.42 to 0.77)
Other types[d]	104	51	112.0	-70.42 (-101.15 to -39.69)	0.64 (0.49 to 0.85)	0.72 (0.53 to 0.98)

HELLP indicates hemolysis, elevated liver enzymes, and low platelet count; HR, hazard ratio; and SMM, severe maternal morbidity.

[a]Estimates are adjusted for maternal age, educational level, maternal height, body mass index, multiple birth, smoking, use of assisted reproductive technology, cohabitation with a partner, country of birth, calendar year of birth, and pregestational diabetes and hypertension prior to first delivery.

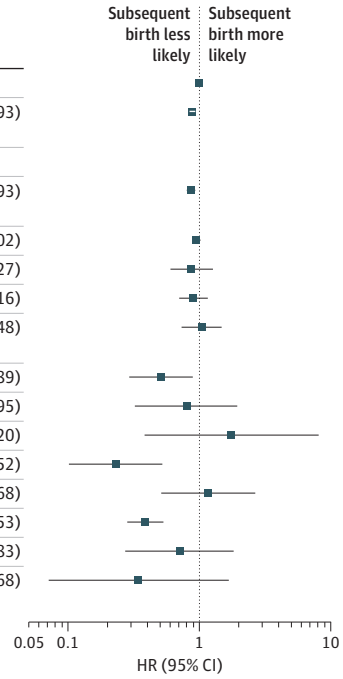
[b]No SMM was the reference group for the primary exposure (composite SMM) and its subtypes.

[c]SMM was defined based on diagnostic and procedure codes in hospital records between 22 weeks of gestation and 42 days postdelivery from the Swedish Medical Birth Register and National Patient Register (for specific codes, see eTable 1 in Supplement 1).

[d]Other types include sickle cell anemia with crisis, acute and subacute liver failure, acute respiratory distress syndrome, and status epilepticus.

Figure 4. Sibling Analysis Among Women With SMM and Their Full Sisters Without SMM the Time of Their First Birth Using Stratified Cox Regression Models, Sweden, 1999-2021

SMM during first birth	Total No. of women	No. with subsequent births	Rate of subsequent births per 1000 person-years	Crude HR (95% CI)	Adjusted HR (95% CI)[a]
Sisters with no SMM (unexposed)[b]	11 306	8557	221.5	1 [Reference]	1 [Reference]
Sisters with any SMM (primary exposure)[c]	9575	6608	170.8	0.83 (0.80 to 0.87)	0.88 (0.84 to 0.93)
Type of SMM					
Severe preeclampsia, HELLP syndrome, eclampsia	4504	2997	165.0	0.80 (0.75 to 0.85)	0.86 (0.80 to 0.93)
Severe hemorrhage	4184	3105	188.8	0.90 (0.85 to 0.96)	0.95 (0.88 to 1.02)
Surgical complications	170	113	130.1	0.70 (0.51 to 0.96)	0.87 (0.60 to 1.27)
Sepsis	363	249	178.7	0.87 (0.70 to 1.09)	0.90 (0.70 to 1.16)
Embolism, disseminated intravascular coagulation, shock	216	141	168.3	0.91 (0.67 to 1.22)	1.04 (0.73 to 1.48)
Cardiac complications	114	39	56.1	0.47 (0.30 to 0.75)	0.51 (0.29 to 0.89)
Acute kidney failure, dialysis	36	18	83.9	0.87 (0.44 to 1.71)	0.80 (0.32 to 1.95)
Severe uterine rupture	10	7	130.1	2.11 (0.49 to 9.11)	1.76 (0.38 to 8.20)
Cerebrovascular accident	60	28	87.9	0.33 (0.17 to 0.61)	0.23 (0.10 to 0.52)
Anesthesia complications	34	25	182.1	1.22 (0.60 to 2.47)	1.17 (0.51 to 2.68)
Severe mental health conditions	307	146	81.9	0.40 (0.30 to 0.52)	0.38 (0.28 to 0.53)
Assisted ventilation	29	13	149.9	0.60 (0.26 to 1.34)	0.71 (0.27 to 1.83)
Other types[d]	16	10	132.4	0.38 (0.12 to 1.18)	0.34 (0.07 to 1.68)



HELLP indicates hemolysis, elevated liver enzymes, and low platelet count; HR, hazard ratio; and SMM, severe maternal morbidity.

[a]Estimates are adjusted for maternal age, educational level, maternal height, body mass index, multiple birth, smoking, use of assisted reproductive technology, cohabitation with a partner, country of birth, calendar year of birth, and pregestational diabetes and hypertension prior to the first delivery.

[b]No SMM was the reference group for the primary exposure (composite SMM) and its subtypes.

[c]SMM was defined based on diagnostic and procedure codes in hospital records between 22 weeks of gestation and 42 days postdelivery from the Swedish Medical Birth Register and National Patient Register (for specific codes, see eTable 1 in Supplement 1).

[d]Other types include sickle cell anemia with crisis, acute and subacute liver failure, acute respiratory distress syndrome, and status epilepticus.

subsequent births are hard to speculate on and may result from multiple factors, such as decreased desire for more children, trauma, infertility related to psychiatric medications, or lack of health counseling. In Sweden, women who have immigrated face a 40% higher risk of life-threatening conditions during childbirth compared with Swedish-born women, largely due to gaps in antenatal care. Asylum seekers and undocumented migrants are particularly vulnerable, experiencing poorer maternal health outcomes and higher risks of inadequate antenatal and postpartum care than refugee women with residency.[47,48] Suboptimal care, including diagnostic failures and treatment delays, could contribute significantly to increased SMM and, in turn, reduced probability of future pregnancy among women with severe mental health conditions at the time of first birth.

Our study has several strengths. First, it is a large, population-based cohort study encompassing data from more than 1 million women during a study period exceeding 22 years. We further used a comprehensive and validated definition of SMM and SMM subtypes that is used for maternal health surveillance in Sweden.[6] Second, we considered several key confounders of the association between SMM and probability of subsequent birth, including assisted reproductive technology use and preexisting medical conditions such as diabetes or hypertension. Third, we also included a sibling analysis in our study, which allowed us to assess potential genetic and familial confounding. Fourth, considering the accelerated risk of death among women with SMM, we computed the estimates taking into account the competing risk of death.

Limitations

Caution is warranted in interpreting our study findings due to certain limitations. Our study focused exclusively on the first and second recorded deliveries, potentially limiting the generalizability of our results to higher-order parities. Additionally, our study did not delve into the underlying mechanisms of the reduced probability of a subsequent birth, highlighting the need for further research in this area. Although no recent study specifically validates hysterectomy using *ICD* codes, research indicates that surgical procedure codes are accurate in 98% of cases,[49] with good validity for major gynecological procedures.[50] Furthermore, this study was conducted in Sweden, and the findings might not be generalizable to other settings with different health care systems. Finally, sibling analyses may be susceptible to residual unmeasured confounding, introducing factors that render siblings incomparable.[51]

Conclusions

In this study, we observed that women with SMM in their first delivery had a reduced likelihood of subsequent birth. Specific complications, such as cardiac issues, severe uterine rupture, mental health conditions, assisted ventilation, and cerebrovascular accident, showed the most significant association. Genetic and familial factors did not explain the observed associations. Adequate reproductive counseling and improved monitoring and antenatal care are crucial for women with a history of SMM.

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Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Tsamantioti, Razaz.
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Administrative, technical, or material support: Razaz.
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