Circulation: Cardiovascular Quality and Outcomes

ORIGINAL ARTICLE

Clinical Features of Myocardial Infarction in Women With a History of Preeclampsia: A Population-Based Cohort Study

Neja Mudrovcic, MD; Elin Tegnesjö, MD; Rasmus Walter Green, MD, PhD; Maria Jonsson, MD, PhD; Christina Christersson, MD, PhD; Lina Bergman, MD, PhD; Karl Bergman, MD; Anna-Karin Wikström, MD, PhD; Susanne Hesselman, MD, PhD

BACKGROUND: Preeclampsia is associated with an increased lifetime risk of myocardial infarction. This study explored whether there is a difference in the clinical features and severity of myocardial infarction in women with previous preeclampsia compared with women with no history of preeclampsia.

METHODS: This register-based cohort study combined data from the Swedish Medical Birth Register with data from the quality register the Swedish Web-System for Enhancement and Development of Evidence-Based Care in Heart Disease Evaluated According to Recommended Therapies. Women with a first singleton birth between 1973 and 2019 were included. The outcome of myocardial infarction was categorized as severe if it resulted in death within 7 days, cardiogenic shock, cardiac arrest, impaired left ventricular systolic function, mechanical complication, or ST-segment–elevation myocardial infarction. The association between preeclampsia and myocardial infarction was investigated using cause-specific hazard models.

RESULTS: Among 1 966 096 women with a first singleton birth, 82 980 (4.2%) had preeclampsia. Myocardial infarction was registered in 10 758 (0.5%) of the total population. One-third (n=3672, 34.1%) of myocardial infarctions had severe features and two-thirds (n=6996, 69.1%) were nonsevere. Preeclampsia was associated with increased risk of myocardial infarction, with an adjusted hazard ratio (HR) of 1.71 (95% CI, 1.50–1.94) for severe and 1.86 (95% CI, 1.71–2.04) for nonsevere myocardial infarction. Myocardial infarction in women with prior preeclampsia compared with women without preeclampsia was associated with a higher risk of death (HR, 3.00 [95% CI, 1.10–8.14]), cardiogenic shock (HR, 1.69 [95% CI, 1.11–2.58]), and impaired left ventricular systolic function (HR, 1.69 [95% CI, 1.11–2.58]), while no association was observed for cardiac arrest (HR, 1.37 [95% CI, 0.98–1.93]), ST-segment–elevation myocardial infarction (HR, 1.01 [95% CI, 0.86–1.18]), or mechanical complication (HR, 0.57 [95% CI, 0.08–4.15]).

CONCLUSIONS: Women with a history of preeclampsia have almost twice the risk of myocardial infarction. Myocardial infarction among women with prior preeclampsia more often results in death, cardiogenic shock, and impaired left ventricular systolic function than among women without preeclampsia.

Key Words: cohort studies ■ heart diseases ■ myocardial infarction ■ pre-eclampsia ■ ST elevation myocardial infarction

It is well established that women with hypertensive disorder of pregnancy have a 2- to 3-fold increased lifetime risk of cardiovascular disease, including hypertension, stroke, and myocardial infarction, with the highest risk being present among women with previous preeclampsia.[1–4] Preeclampsia and atherosclerosis share features of vascular inflammation with associated endothelial dysfunction.[5] In addition, morbidities such as obesity, diabetes, dyslipidemia, and chronic hypertension that predispose women to preeclampsia are also risk factors for myocardial infarction.[6,7] It is unclear whether preeclampsia causes additional and persisting endothelial injury or whether it is merely a

Correspondence to: Neja Mudrovcic, Kvinnokliniken, Nyköpings lasarett, 611 85 Nyköping, Sweden. Email neja.mudrovcic@uu.se
Supplemental Material is available at https://www.ahajournals.org/doi/suppl/10.1161/CIRCOUTCOMES.124.011442.
For Sources of Funding and Disclosures, see page 395.

Circulation: Cardiovascular Quality and Outcomes is available at http://www.ahajournals.org/journal/circoutcomes

WHAT IS KNOWN

- Previous preeclampsia increases the risk of myocardial infarction later in life.
- Knowledge is sparse about the clinical features and severity of myocardial infarction in women with a history of preeclampsia.

WHAT THE STUDY ADDS

- The risk is increased for both severe and nonsevere forms of myocardial infarction.
- Myocardial infarction in women with a history of preeclampsia is associated with a higher risk of death, cardiogenic shock, and impaired left ventricular systolic function than in women with no preeclampsia.

Nonstandard Abbreviations and Acronyms

BMI	body mass index
HR	hazard ratio
MBR	Swedish Medical Birth Register
STEMI	ST-segment–elevation myocardial infarction
SWEDEHEART	The Swedish Web-system for Enhancement and Development of Evidence-based care in Heart disease Evaluated According to Recommended Therapies

stress test for future cardiovascular disease. The excessive dyslipidemia, inflammation, and endothelial dysfunction in preeclampsia could potentially cause permanent vascular damage and promote future atherosclerosis.[8,9] Compared with women with normotensive pregnancies, women with preeclampsia demonstrate coronary atherosclerosis earlier in life[10] and experience myocardial infarction at younger ages.[11,12] Furthermore, subclinical coronary artery disease has been found after preeclampsia even among women estimated to be at low cardiovascular risk.[13]

Despite this well-known association with future cardiovascular risk, knowledge is sparse about the clinical features and severity of myocardial infarction in women with a history of preeclampsia. Previous studies are few, small, and show conflicting results. In 3 cohort studies with 200 to 400 participants,[11,12,14] 2 studies found higher rates of ST-segment–elevation myocardial infarction (STEMI) and 1 found no difference in the rates of STEMI among women with a history of preeclampsia compared with women without a history of preeclampsia. No increased risk of cardiogenic shock or impaired left ventricular systolic function after a myocardial infarction was observed among women with preeclampsia.[11]

Taken together, there is a gap in knowledge about the severity and type of myocardial infarction in women with a history of preeclampsia, in particular at a large scale and population-based level. Therefore, we investigated whether there is a difference in the clinical features and severity of myocardial infarction among women with a history of preeclampsia compared with women without a history of preeclampsia in Sweden, using nationwide registers with detailed information on pregnancy exposures and myocardial infarctions.[15]

METHODS

The data, analytic methods, and study materials will not be made available to other researchers for purposes of reproducing the results or replicating the procedure but can be applied for from the National Board of Health and Welfare in Sweden, Statistics Sweden, and the quality register the Swedish Web-system for Enhancement and Development of Evidence-based care in Heart disease Evaluated According to Recommended Therapies (SWEDEHEART) after ethical approval.

Study Design and Data Sources

This register-based cohort study used data at an individual level from several Swedish national registers. A personal identification number allowed identification and merging of data from participants across the registers.[16]

The Swedish Medical Birth Register (MBR) covers information obtained from health care services on >98% of all births in Sweden since 1973. Self-reported information on maternal health and socioeconomic and behavioral factors is collected prospectively by midwives at antenatal care clinics. At discharge from the hospital after childbirth, maternal disorders and complications during pregnancy and birth and information on the neonate are registered in electronic birth records by checkboxes and by diagnoses according to the *International Classification of Diseases* codes.[17] In this study, information from the MBR was linked to the Swedish National Patient Register, providing diagnostic codes from inpatient and outpatient clinics.[18] Date and cause of death were collected from the Cause-of-Death Register.[19] We received information about educational attainment from the Register on Participation in Education, and information on maternal birth country and emigration was retrieved from the Total Population Register (Statistics Sweden).

SWEDEHEART is a medical quality register of coronary artery disease care and procedures, with national coverage since 1995. Initially, it only included admissions to cardiac intensive care units. Since 2004, all patients with a suspected myocardial infarction have been included. Over 100 clinical variables are collected during the hospital stay: interventions, results of examinations, complications, and diagnoses. Data quality and accuracy in SWEDEHEART are monitored yearly, and the internal validity is high.[15]

Study Population

Women with a first singleton birth between 1973 and 2019 were identified in the MBR. Women with a myocardial infarction before pregnancy (n=86), women who died (n=4660), emigrated (n=54 199), or had a diagnosis of myocardial infarction registered in the National Patient Register or Cause-of-Death Register (n=446) before the start of the follow-up in January

1995 were excluded (Figure). Characteristics of women with a myocardial infarction after pregnancy but before the start of follow-up are described in a drop-out analysis (Table S1).

Analysis of clinical characteristics was restricted to women with myocardial infarction (n=10 758) in the study population.

Exposure

Exposure was preeclampsia during the first pregnancy according to the *International Classification of Diseases* diagnostic codes in the medical records (Table S1). Criteria for the disease during the corresponding time period were used, including hypertension after 20 weeks of gestation and proteinuria or end-organ injury. Women with only gestational hypertension or chronic hypertension were treated as unexposed.

Outcome

The outcome was the severity of the first myocardial infarction during the period from January 1, 1995, to December 31, 2020, registered in SWEDEHEART, and confirmed by a corresponding *International Classification of Diseases* code registered in the Swedish National Patient Register or the Cause-of-Death Register (Table S1). Clinical information on the myocardial infarction was registered in SWEDEHEART by the treating physicians and health administrators.

The definition of severe myocardial infarction, encompassing myocardial infarctions with an increased risk of mortality and long-term morbidity, was based on a clinical judgment by senior cardiologists in the research team (C.C. and K.B.). We defined severe myocardial infarction as a myocardial infarction resulting in death within 7 days, cardiogenic shock, cardiac arrest, impaired left ventricular systolic function, mechanical complications, or STEMI. Cardiogenic shock was diagnosed on admission or during the hospital stay and was defined as persistent systolic blood pressure below 90 mm Hg with signs of tissue hypoperfusion that were not due to hypovolemia. Impaired left ventricular systolic function was defined as a de novo ejection fraction of <40% measured by echocardiography. Mechanical complications included left ventricular free wall rupture, postinfarction ventricular septum defect, or acute mitral regurgitation. STEMI was defined as a significant ST-segment elevation on the arrival ECG according to the Universal Definition of Myocardial Infarction, assessed by the physician in charge.[20]

Covariates

The MBR provided information on pregnancy characteristics and maternal age at birth (categorized into <20, 20–34, and >35 years). Information on pregestational diabetes, chronic hypertension, systemic lupus erythematosus, and chronic kidney disease (yes/no) was collected by checkboxes. Body mass index (BMI), categorized into <30 and ≥30 kg/m^2 based on maternal height and early pregnancy weight, smoking (yes/no), and family situation (categorized as married/cohabiting or other) were reported at the first antenatal visit. BMI and smoking have been registered in the MBR since 1982. Educational attainment was categorized into less than secondary education, secondary education, and tertiary education, and maternal birth country into 3 groups: Sweden, Europe/North America/Oceania, and the rest of the world.

Birth characteristics included year of birth in strata of decades, infant birth weight (g), and gestational age in weeks. Preterm birth was defined as delivery of an infant <37 weeks of gestation, and an infant small for gestational age was defined as sex- and gestational age-adjusted weight <2.5th percentile, indicating intrauterine growth restriction.[21]

Statistical Analysis

Descriptive maternal baseline characteristics were tabulated and presented as frequencies (%) or means with SDs according to exposure (ie, preeclampsia). The association between preeclampsia and myocardial infarction was investigated using cause-specific hazard models. These models accounted for the competing risks from various severities of myocardial infarction

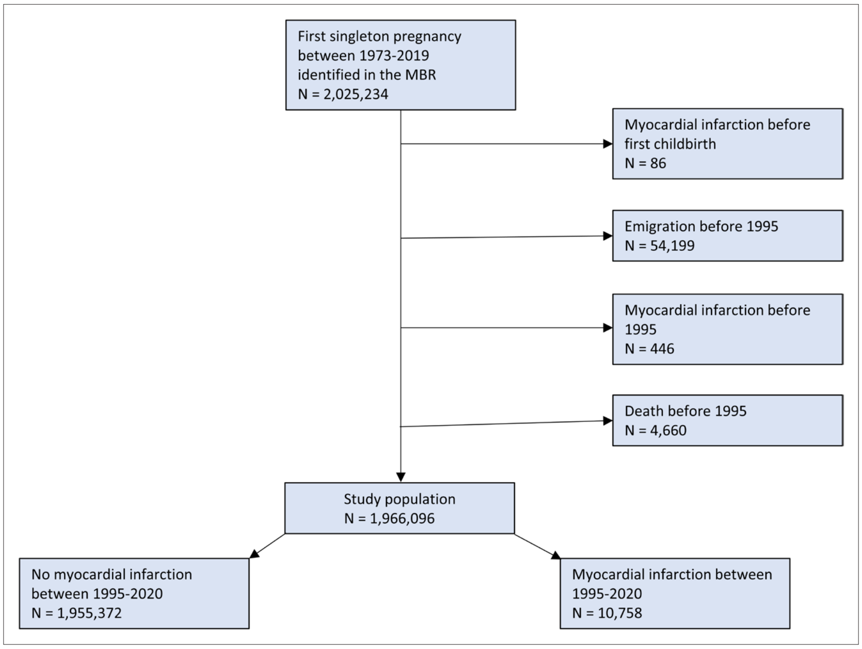

Figure. Study population.
MBR indicates Swedish Medical Birth Register.

and death from myocardial infarction as well as other causes of deaths. The results are reported as hazard ratios (HRs) with 95% CIs, the reference group being women without preeclampsia.[22] Proportional hazard assumption was checked visually by inspecting log-(log) survival plots for all investigated variables. Adjusted models included maternal age (as a continuous variable), country of birth, cohabitation, maternal education level, year of birth, and prepregnancy medical conditions as covariates identified by directed acyclic graphs[23] and a theoretical framework (Figure S1). For the subgroup of women who gave birth in 1982 or later, the models also included the covariates BMI (continuous) and smoking status.

In an exploratory subanalysis, the adjusted model also included gestational length at birth and small for gestational age infant, potential mediators, and interaction factors between preeclampsia and cardiovascular disease.[24]

To investigate a potential immortal time bias, a sensitivity analysis including only women with births from 1995 and onward was performed.

Data were analyzed using SPSS software, version 28.0 (IBM Corp, Armonk, NY) and R, version 4.3.2, using the survival add-on package.[25]

The study was approved by the regional ethics committee of Uppsala (log number 2019-04925 approved January 28, 2020, with a supplement 2022-00922-02 approved March 3, 2022). Pseudonymization of merged data was done by the National Board of Health and Welfare.

RESULTS

The study cohort included 1 966 096 women with a first singleton birth between 1973 and 2019, among whom 82 980 women had preeclampsia (4.2%). Women with preeclampsia had a higher mean age and BMI at the time of pregnancy than women without preeclampsia. In addition, pregestational chronic disease and other pregnancy complications were more common in the group with preeclampsia (Table 1).

The mean age at the end of follow-up was 49.7±12.8 years for women with preeclampsia and 49.9±13.0 years for women without preeclampsia (Table 2). The mean follow-up time with a start on January 1, 1995, was 18.2±8.6 years for women with preeclampsia and 17.9±8.5 years for women without preeclampsia. In all, 10 758 women (0.5%) had a myocardial infarction registered in SWEDEHEART between 1995 and 2020. Of these, 3672 (34.1%) were classified as myocardial infarction with severe features, and 6996 (65.9%) were classified as nonsevere. Preeclampsia was associated with increased risk of myocardial infarction, both severe (adjusted HR, 1.71 [95% CI, 1.50–1.94]) and nonsevere (adjusted HR, 1.86 [95% CI, 1.71–2.04]), compared with women without preeclampsia (Table 2; Figure S2). After restricting the population to births after 1982 to include BMI and smoking as additional confounders, the association between preeclampsia and myocardial infarction remained (adjusted HR, 2.05 [95% CI, 1.81–2.33]; Table S2). When the birth of a small for gestational age infant

Table 1. Baseline Characteristics of the Study Population (n=1 966 096)

	Women, No. (%)	
	No preeclampsia	Preeclampsia
Maternal characteristic	n=1 883 116	n=82 980
Age at birth, y		
Mean (SD)	26.8 (5.0)	27.2 (5.3)
<20	111 186 (5.9)	4587 (5.5)
20–34	1 631 853 (86.7)	70 166 (84.6)
≥35	140 077 (7.4)	8227 (9.9)
Preexisting comorbidities		
Pregestational diabetes	7330 (0.4)	1476 (1.8)
Chronic hypertension	4300 (0.2)	886 (1.1)
SLE	1336 (0.1)	111 (0.1)
Kidney disease	6256 (0.3)	523 (0.6)
BMI in early pregnancy, kg/m²*		
Mean (SD)	23.6 (4.1)	25.5 (5.2)
<30	1 149 332 (74.5)	46 280 (66.9)
≥30	93 976 (6.1)	9739 (14.1)
Missing	299 436 (19.4)	13 185 (19.1)
Smoking*	200 257 (13.0)	6480 (9.4)
Missing	102 729 (6.7)	4736 (6.8)
Family situation		
Cohabitation/married	1 474 969 (78.3)	65 908 (79.4)
Other	278 269 (14.8)	11 305 (13.6)
Missing	129 878 (6.9)	5767 (6.9)
Educational level		
Tertiary education	902 205 (47.9)	37 481 (45.2)
Secondary education	389 966 (20.7)	18 765 (22.6)
Less than secondary education	583 267 (31.0)	26 462 (31.9)
Missing	7678 (0.4)	272 (0.3)
Country of birth		
Sweden	1 586 217 (84.2)	72 893 (87.9)
Europe, North America, and Oceania	151 703 (8.1)	5253 (6.3)
Rest of the world	144 866 (7.7)	4822 (5.8)
Missing	303 (0.0)	12 (0.0)
Birth characteristics		
Birth year		
1973–1980	396 273 (16.3)	12 250 (14.8)
1981–1990	380 670 (20.2)	15 727 (19.0)
1991–2000	376 289 (20.0)	17 642 (21.3)
2001–2010	416 781 (22.1)	18 663 (22.5)
2011–2019	403 103 (21.4)	18 698 (22.5)
Birth weight, g; mean (SD)	3452 (540)	3101 (822)
Missing	4852 (0.3)	288 (0.3)
Small for gestational age	66 162 (3.5)	11 275 (13.6)
Missing	8184 (0.4)	453 (0.5)
Gestational length, wk; mean (SD)	39.9 (1.9)	38.5 (3.0)
Preterm birth	100 462 (5.3)	16 766 (20.2)
Missing	3420 (0.2)	170 (0.2)

BMI indicates body mass index; and SLE, systemic lupus erythematosus.
*From 1982, N=1 611 948 (82% of the total population).

Table 2. Rates and Risk for MI According to Severity After Preeclampsia

	No preeclampsia	Preeclampsia	*P* value
N (total)	1 883 116	82 980	
MI (%)	9960 (0.5)	798 (1.0)	<0.001
Sum of follow-up, y	34 281 486	1 486 867	
Mean age at end of follow-up (SD)	49.9 (13.0)	49.7 (12.8)	<0.001
Rate/10 000 PYAR (95% CI)	2.91 (2.85–2.96)	5.36 (4.99–5.74)	
Crude HR (95% CI)	1.00	1.86 (1.73–2.00)	
Adjusted HR (95% CI)	1.00	1.81 (1.68–1.95)	
Severe MI* (%)	3413 (0.2)	259 (0.3)	<0.001
Rate/10 000 person-years (95% CI)	1.00 (0.96–1.03)	1.74 (1.54–1.97)	
Age at time of severe MI (SD)	57.7 (8.6)	56.2 (10.2)	0.024
Crude HR (95% CI)	1.00	1.76 (1.55–2.00)	
Adjusted HR (95% CI)	1.00	1.71 (1.50–1.94)	
Nonsevere MI† (%)	6547 (0.3)	539 (0.6)	<0.001
Rate/10 000 person-years (95% CI)	1.91 (1.86–1.96)	3.63 (3.33–3.94)	
Age at time of nonsevere MI (SD)	55.6 (9.1)	54.1 (9.0)	<0.001
Crude HR (95% CI)	1.00	1.92 (1.76–2.09)	
Adjusted HR (95% CI)	1.00	1.86 (1.71–2.04)	

Adjusted for birth year, education level, cohabitation, comorbidities at pregnancy (pregestational diabetes, chronic hypertension, systemic lupus erythematosus, and chronic kidney disease), maternal age, and country of birth. HR indicates hazard ratio; MI, myocardial infarction; and PYAR, person-years-at-risk.

*Nonsevere myocardial infarction excluded from analysis.

†Severe myocardial infarction excluded from analysis.

and gestational length at birth were added as covariates, the results were attenuated (adjusted HR of 1.63 [95% CI, 1.52–1.76] for overall myocardial infarction, adjusted HR of 1.51 [95% CI, 1.33–1.73] for severe myocardial infarction, and adjusted HR of 1.70 [95% CI, 1.55–1.86] for nonsevere myocardial infarction; Table S3). Sensitivity analysis of births after 1995 showed that preeclampsia was associated with both severe (adjusted HR, 2.32 [95% CI, 2.12–3.52]) and nonsevere myocardial infarction (adjusted HR, 2.56 [95% CI, 1.79–3.65]; Table S2).

Women With Myocardial Infarction

Among women with myocardial infarction, the risk of the composite outcome of severe myocardial infarction was not greater for women with a history of preeclampsia compared with those with no history of preeclampsia (adjusted HR, 1.10 [95% CI, 0.96–1.25]). When including the whole population with myocardial infarction and investigating the subcomponents of severe myocardial infarction, women with a history of preeclampsia had an increased risk of death at the time of infarction (0.6% versus 0.3%; adjusted HR, 3.00 [95% CI, 1.10–8.14]), cardiogenic shock (3.3% versus 2.4%; adjusted HR, 1.69 [95% CI, 1.11–2.58]), and impaired left ventricular systolic function (10.0% versus 7.9%; adjusted HR, 1.49 [95% CI, 1.19–1.88]) compared with women without a history of preeclampsia. There was no increased risk for cardiac arrest, STEMI, or mechanical complications at the time of myocardial infarction in women with a history of preeclampsia (Table 3).

A drop-out analysis of women with a diagnosis of myocardial infarction after pregnancy but before the start of follow-up in 1995 (n=401) showed that preeclampsia (10.4% versus 4.2%), pregestational diabetes (19.0% versus 1.8%), and chronic hypertension (7.1% versus 1.1%) were more common among women in this group than among women in the included cohort (Table S4).

DISCUSSION

Women with a history of preeclampsia in the first pregnancy had an almost 2-fold increased risk of myocardial infarction, encompassing both severe and nonsevere forms, compared with women without preeclampsia. In the population of women with myocardial infarction, the proportion of severe myocardial infarction was not different in women with a history of preeclampsia compared with those with no preeclampsia. Women with prior preeclampsia who suffered from a myocardial infarction more often experienced cardiogenic shock, impaired left ventricular systolic function, and increased short-term mortality than those women with a myocardial infarction without a history of preeclampsia.

Research in Context

Our results are concordant with numerous earlier studies showing that the risk of myocardial infarction is almost double in women with a history of preeclampsia.[4,26–28] There is no standard definition of severe myocardial infarction. The definition in our study was based on a clinical judgment of factors associated with long-term morbidity or mortality after myocardial infarction. There was the same proportion of the composites of severe (approximately one third) and nonsevere (approximately two thirds) myocardial infarctions in women with or without previous preeclampsia.

We found that women with prior preeclampsia more commonly presented with cardiogenic shock and impaired left ventricular systolic function at the time of myocardial infarction. Left ventricular ejection fraction is one of the strongest predictors of both in-hospital and long-term prognosis in myocardial infarction and a major predictor of mortality[29] and future ischemic events.[30,31]

Table 3. HRs of Specific Clinical Characteristics in the Group of Women With Myocardial Infarction According to Preeclampsia (n=10 758)

	No preeclampsia	Preeclampsia	Crude HR	Adjusted HR
Nonsevere myocardial infarction	6547 (65.7)	539 (67.5)		
Severe myocardial infarction	3413 (34.3)	259 (32.5)	1.11 (0.98–1.26)	1.10 (0.96–1.25)
Death	26 (0.3)	5 (0.6)	2.29 (1.11–7.52)	3.00 (1.10–8.14)
Cardiac arrest	433 (4.3)	40 (5.0)	1.34 (0.97–1.86)	1.37 (0.98–1.93)
Cardiac shock	239 (2.4)	26 (3.3)	1.55 (1.04–2.33)	1.69 (1.11–2.58)
STEMI	2785 (28.0)	196 (24.6)	1.04 (0.90–1.20)	1.01 (0.86–1.18)
Mechanical complication*	31 (0.3)	1 (0.1)	0.48 (0.06–3.52)	0.57 (0.08–4.15)
Impaired left ventricular systolic function†	783 (7.9)	80 (10.0)	1.49 (1.19–1.88)	1.56 (1.22–1.98)

Adjusted for birth year, education level, cohabitation, comorbidities at pregnancy (pregestational diabetes, chronic hypertension, systemic lupus erythematosus, and chronic kidney disease), maternal age, and country of birth. HR indicates hazard ratio; and STEMI, ST-segment–elevation myocardial infarction.

*Left ventricular free wall rupture, postinfarction ventricular septum defect, or acute mitral regurgitation.

†De novo ejection fraction of <40% measured by echocardiography.

Cardiogenic shock is a leading cause of in-hospital death, with a mortality rate of ≈50%.[32] In contrast to our findings, a retrospective cohort study found similar rates of cardiogenic shock and impaired left ventricular systolic function among women with and without a history of preeclampsia.[11] This discrepancy in findings might be explained by a potential low statistical power of the cited study, which only included 391 women.

The largest component of the composite outcome severe myocardial infarction was STEMI. Despite advances in treatment, STEMI continues to be associated with a higher mortality rate than non-STEMI.[33] We did not find an increased risk of STEMI in women with previous preeclampsia. This is in contrast to a prospective cohort of 251 women that showed that STEMI was more prevalent in women with a self-reported history of preeclampsia.[12] This difference may be explained by random variation due to small sample size or potential issues with recall bias in the cited study. However, our findings are in line with another cohort study of 391 women that found no higher risk of STEMI in the group of women with previous preeclampsia.[11] A recent study showed that preterm, but not term, preeclampsia was associated with an increased risk of STEMI, which may explain the discrepancies between the different studies.[34]

Strengths and Limitations

This is the first study investigating clinical features of myocardial infarction after preeclampsia in a large population-based cohort encompassing over 10 000 events of myocardial infarction. Our study used data from validated Swedish national registers, reducing selection bias and reflecting real-life data in the Swedish health care system.[17,18] The quality register SWEDEHEART contains a wide range of individual patient information and covers >90% of myocardial infarctions in Sweden. The information in the register is considered reliable, and the register is validated regularly.[35] Information on exposure and outcomes was collected independently, avoiding recall bias.

We recognize that there are limitations to this observational study. There was up to 6 percent missing data for certain pregnancy characteristics; however, it was equally balanced between groups. The composite severe was based on clinical judgment and not on a well-defined classification of myocardial infarction, such as the type of myocardial infarction.[36] The criteria were decided on before the start of the analysis, which we consider a strength. Our study spans several decades during which the criteria for inclusion in SWEDEHEART have differed. Since the SWEDEHEART register was established nationally in 1995, women with myocardial infarction before that year could not be included, potentially introducing immortal time bias. To investigate this, we analyzed characteristics of women with myocardial infarction before 1995 in a drop-out analysis. Prepregnancy hypertension, diabetes, and preeclampsia were more commonly found in the excluded group, which probably means that the onset of myocardial infarction was earlier in this group. This should bias our result toward the null. In a sensitivity analysis including only women with first births after 1995, preeclampsia was associated with an over 2-fold risk of both severe and nonsevere myocardial infarctions. During the years 1995 to 2003, patients with myocardial infarction who did not receive intensive care were not included in SWEDEHEART,[37] thus restricting registration of myocardial infarctions to the more severe forms before 2003. This could have resulted in a higher detection rate of severe forms because a history of preeclampsia is associated with earlier onset of myocardial infarction, although the majority of infarctions (9769/10 758) in this study population occurred after 2003. We did not find an increased risk of severe compared with nonsevere forms of myocardial infarction overall, but the increased risk of cardiogenic shock, impaired left ventricular systolic function, and increased mortality could be a result of information bias.

As the incidence of preeclampsia is significantly higher in nulliparous compared with parous women, we decided to restrict our exposure status to preeclampsia during the first pregnancy. The major drawback of only including nulliparous individuals is not being able to study the effect of recurrent preeclampsia on the severity of myocardial infarction. Recurrent preeclampsia has been linked to a higher risk of cardiovascular disease later in life.[38] We can only speculate that women with recurrent preeclampsia would have a higher risk for complications of myocardial infarction compared with women with preeclampsia only in their first pregnancy. We think that the small proportion of women with no preeclampsia in the first pregnancy but preeclampsia in a subsequent pregnancy will be wrongly classified as nonexposed and bias the results towards null.

Due to the nature of an observational study, confounding must be acknowledged and dealt with. We used directed acyclic graphs[23] to identify confounders and did not consider comorbidities and other factors present at the time of the event as covariates or explanatory factors.

Preeclampsia can, therefore, still be only a marker of an adverse cardiovascular profile in this group of women and not directly associated with myocardial infarction severity.

Clinical and Research Implications

We find that certain severe features of myocardial infarction were more common in women with previous preeclampsia, highlighting the importance of an awareness of women's pregnancy history in the treatment and prevention of ischemic heart disease.

The underlying mechanisms behind this increased risk are unknown, though several hypotheses have been proposed.[34] Vascular dysfunction persists years after a pregnancy affected by preeclampsia.[39] Reduced endothelium-dependent vasodilation, alterations in the vasoconstrictor angiotensin II system, and increased inflammatory factors such as C-reactive protein, vascular cell adhesion molecule-1, and intercellular adhesion molecule-1 are potential contributors to vascular dysfunction.[40] Structural cardiovascular changes have been shown in women with preeclampsia with thicker left ventricular septal and posterior walls, higher myocardial mass, and increased carotid intima-media thickness compared with controls.[41]

Women have higher rates of cardiogenic shock and mortality complicating myocardial infarction compared with men.[42–44] While this difference may largely reflect disparities in management, some studies have shown differences in clinical presentation, with higher acuity in women presenting with cardiogenic shock.[45] Although not investigated, adverse obstetric history, including preeclampsia, might contribute to this sex difference.

Clinical care of patients with myocardial infarction has evolved over the period studied. However, our findings persist despite these changes. It is important to note that data representing the current standard of care could potentially be more applicable to clinical practice. Historically, women have been underrepresented in cardiovascular science, and clinical practice guidelines are based on studies where women remain underrepresented.[46] Our study provides valuable insights into the impact of a women-specific risk factor on the presentation and severity of myocardial infarction.

Measures to prevent or delay the onset of preeclampsia during pregnancy include low-dose aspirin and adequate blood pressure control. This in turn could potentially reduce inflammatory, vascular, and cardiac remodulation, factors that all have been linked to the increased risk of cardiovascular disorders later in life.[47–50] In the years and decades after a pregnancy with preeclampsia, up to one third of women develop chronic hypertension, a well-established risk factor for ischemic heart disease, highlighting the need for close follow-up after preeclampsia.[51,52] Recently, two randomized controlled trials have shown an association between self-monitoring of blood pressure and lower blood pressure 6 months postpartum.[53,54] Moreover, preeclampsia is associated with an increased risk of dyslipidemia, a known risk factor for myocardial infarction.[55] Statins, metformin, and aspirin have been suggested as potential pharmacological agents in postpartum cardiovascular disease prevention, but their role in women with a history of preeclampsia remains uncertain.[56] Aspirin use in women with prior hypertensive disorder of pregnancy has been associated with reduced risk of stroke.[57] Several international practice guidelines recommend follow-up care for women with a history of preeclampsia in the years after pregnancy, with the most recent ESC guidelines advocating annual monitoring.[58,59] Future prospective studies are needed to investigate potential modifiable risk factors in women with previous preeclampsia, such as health and lifestyle interventions or use of drugs to reduce their risk of future myocardial infarction.

Conclusions

Women with a history of preeclampsia have a nearly 2-fold increased risk of myocardial infarction later in life. Myocardial infarction among women with prior preeclampsia more often results in death, cardiogenic hock, and impaired left ventricular systolic function than in women with no previous preeclampsia.

ARTICLE INFORMATION

Received September 4, 2024; accepted March 10, 2025.

Affiliations

Departments of Women's and Children's Health (N.M., E.T., M.J., A.-K.W., S.H.) and Medical Sciences, Cardiology (C.C.), Uppsala University, Sweden. Centre for Clinical Research Sörmland, Uppsala University, Eskilstuna, Sweden (N.M.). Department of Clinical Science and Education, Karolinska Institute, Stockholm, Sweden

(R.G.). Department of Obstetrics and Gynecology, Institute of Clinical Sciences (L.B.) and Department of Molecular and Clinical Medicine, Institute of Medicine (K.B.), Sahlgrenska Academy, University of Gothenburg, Sweden. Department of Obstetrics and Gynecology, Stellenbosch University, Cape Town, South Africa (L.B.). Division of Cardiology, Department of Medicine, Tygerberg Hospital and Stellenbosch University, Cape Town, South Africa (K.B.). Centre for Clinical Research Dalarna, Uppsala University, Falun, Sweden (S.H.).

Acknowledgments

The authors thank Erik Lampa, biostatistician, Epistat AB. Drs Wikström, Christersson, Hesselman, Bergman, and Bergman conceived the study. Drs Mudrovcic and Tegnesjö managed the data set and performed the statistical analysis with technical and intellectual support of Drs Wikström, Hesselman, and Green. Dr Mudrovcic wrote the first draft. All authors provided intellectual and methodological feedback on the analysis and manuscript and approved the submitted work.

Sources of Funding

Dr Mudrovcic was supported by the Centre for Clinical Research Sörmland, Uppsala University, Eskilstuna, Sweden. Dr Hesselman was supported by the Centre for Clinical Research, Falun, Sweden. Dr Bergman was supported by the Wallenberg Center for Molecular and Translational Medicine.

Disclosures

None.

Supplemental Material

Tables S1–S4
Figures S1–S2

REFERENCES

1. Okoth K, Chandan JS, Marshall T, Thangaratinam S, Thomas GN, Nirantharakumar K, Adderley NJ. Association between the reproductive health of young women and cardiovascular disease in later life: umbrella review. *BMJ*. 2020;371:m3502. doi: 10.1136/bmj.m3502
2. Täufer Cederlöf E, Lundgren M, Lindahl B, Christersson C. Pregnancy complications and risk of cardiovascular disease later in life: a nationwide cohort study. *J Am Heart Assoc*. 2022;11:e023079. doi: 10.1161/JAHA.121.023079
3. Grandi SM, Filion KB, Yoon S, Ayele HT, Doyle CM, Hutcheon JA, Smith GN, Gore GC, Ray JG, Nerenberg K, et al. Cardiovascular disease-related morbidity and mortality in women with a history of pregnancy complications: systematic review and meta-analysis. *Circulation*. 2019;139:1069–1079. doi: 10.1161/CIRCULATIONAHA.118.036748
4. Wikström AK, Haglund B, Olovsson M, Lindeberg SN. The risk of maternal ischaemic heart disease after gestational hypertensive disease. *BJOG*. 2005;112:1486–1491. doi: 10.1111/j.1471-0528.2005.00733.x
5. Staff AC, Redman CWG, Williams D, Leeson P, Moe K, Thilaganathan B, Magnus P, Steegers EAP, Tsigas EZ, Ness RB, et al; Global Pregnancy Collaboration (CoLab). Pregnancy and long-term maternal cardiovascular health. *Hypertension*. 2016;67:251–260. doi: 10.1161/HYPERTENSIONAHA.115.06357
6. Sohlberg S, Stephansson O, Cnattingius S, Wikström AK. Maternal body mass index, height, and risks of preeclampsia. *Am J Hypertens*. 2012;25:120–125. doi: 10.1038/ajh.2011.175
7. O'Brien TE, Ray JG, Chan WS. Maternal body mass index and the risk of preeclampsia: a systematic overview. *Epidemiology*. 2003;14:368–374. doi: 10.1097/00001648-200305000-00020
8. Spracklen CN, Smith CJ, Saftlas AF, Robinson JG, Ryckman KK. Maternal hyperlipidemia and the risk of preeclampsia: a meta-analysis. *Am J Epidemiol*. 2014;180:346–358. doi: 10.1093/aje/kwu145
9. Bonetti PO, Lerman LO, Lerman A. Endothelial dysfunction: a marker of atherosclerotic risk. *Arterioscler Thromb Vasc Biol*. 2003;23:168–175. doi: 10.1161/01.atv.0000051384.43104.fc
10. Hauge MG, Damm P, Kofoed KF, Ersbøll AS, Johansen M, Sigvardsen PE, Møller MB, Fuchs A, Kühl JT, Nordestgaard BG, et al. Early coronary atherosclerosis in women with previous preeclampsia. *J Am Coll Cardiol*. 2022;79:2310–2321. doi: 10.1016/j.jacc.2022.03.381
11. Countouris ME, Koczo A, Reynolds HR, Hausvater A, Mann H, Wang Y, Sharbaugh D, Thoma FW, Mulukutla SR, Catov JM, et al. Characteristics of premature myocardial infarction among women with prior adverse pregnancy outcomes. *JACC Adv*. 2023;2:100411. doi: 10.1016/j.jacadv.2023.100411
12. Grand'Maison S, Pilote L, Schlosser K, Stewart DJ, Okano M, Dayan N. Clinical features and outcomes of acute coronary syndrome in women with previous pregnancy complications. *Can J Cardiol*. 2017;33:1683–1692. doi: 10.1016/j.cjca.2017.08.025
13. Sederholm Lawesson S, Swahn E, Pihlsgård M, Andersson T, Angerås O, Bacsovics Brolin E, Bergdahl E, Blomberg M, Christersson C, Gonçalves I, et al. Association between history of adverse pregnancy outcomes and coronary artery disease assessed by coronary computed tomography angiography. *JAMA*. 2023;329:393–404. doi: 10.1001/jama.2022.24093
14. McDonald EG, Dayan N, Pelletier R, Eisenberg MJ, Pilote L. Premature cardiovascular disease following a history of hypertensive disorder of pregnancy. *Int J Cardiol*. 2016;219:9–13. doi: 10.1016/j.ijcard.2016.05.053
15. Jernberg T, Attebring MF, Hambraeus K, Ivert T, James S, Jeppsson A, Lagerqvist B, Lindahl B, Stenestrand U, Wallentin L. The Swedish Web-system for enhancement and development of evidence-based care in heart disease evaluated according to recommended therapies (SWEDEHEART). *Heart*. 2010;96:1617–1621. doi: 10.1136/hrt.2010.198804
16. Ludvigsson JF, Otterblad-Olausson P, Pettersson BU, Ekbom A. The Swedish personal identity number: possibilities and pitfalls in healthcare and medical research. *Eur J Epidemiol*. 2009;24:659–667. doi: 10.1007/s10654-009-9350-y
17. Cnattingius S, Källén K, Sandström A, Rydberg H, Månsson H, Stephansson O, Frisell T, Ludvigsson JF. The Swedish medical birth register during five decades: documentation of the content and quality of the register. *Eur J Epidemiol*. 2023;38:109–120. doi: 10.1007/s10654-022-00947-5
18. Ludvigsson JF, Andersson E, Ekbom A, Feychting M, Kim JL, Reuterwall C, Heurgren M, Olausson PO. External review and validation of the Swedish national inpatient register. *BMC Public Health*. 2011;11:450. doi: 10.1186/1471-2458-11-450
19. Brooke HL, Talbäck M, Hörnblad J, Johansson LA, Ludvigsson JF, Druid H, Feychting M, Ljung R. The Swedish cause of death register. *Eur J Epidemiol*. 2017;32:765–773. doi: 10.1007/s10654-017-0316-1
20. Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, White HD; Executive Group on behalf of the Joint European Society of Cardiology (ESC)/American College of Cardiology (ACC)/American Heart Association (AHA)/World Heart Federation (WHF) Task Force for the Universal Definition of Myocardial Infarction. Fourth universal definition of myocardial infarction (2018). *J Am Coll Cardiol*. 2018;72:2231–2264. doi: 10.1016/j.jacc.2018.08.1038
21. Marsál K, Persson PH, Larsen T, Lilja H, Selbing A, Sultan B. Intrauterine growth curves based on ultrasonically estimated foetal weights. *Acta Paediatr*. 1996;85:843–848. doi: 10.1111/j.1651-2227.1996.tb14164.x
22. Austin PC, Fine JP. Practical recommendations for reporting Fine-Gray model analyses for competing risk data. *Stat Med*. 2017;36:4391–4400. doi: 10.1002/sim.7501
23. Digitale JC, Martin JN, Glymour MM. Tutorial on directed acyclic graphs. *J Clin Epidemiol*. 2022;142:264–267. doi: 10.1016/j.jclinepi.2021.08.001
24. Ying W, Catov JM, Ouyang P. Hypertensive disorders of pregnancy and future maternal cardiovascular risk. *J Am Heart Assoc*. 2018;7:e009382. doi: 10.1161/JAHA.118.009382
25. Therneau TM. A package for survival analysis in R; 2024. https://CRAN.R-project.org/package=survival
26. Wu P, Haththotuwa R, Kwok CS, Babu A, Kotronias RA, Rushton C, Zaman A, Fryer AA, Kadam U, Chew-Graham CA, et al. Preeclampsia and future cardiovascular health. *Circ Cardiovasc Qual Outcomes*. 2017;10:e003497. doi: 10.1161/CIRCOUTCOMES.116.003497
27. Bellamy L, Casas JP, Hingorani AD, Williams DJ. Pre-eclampsia and risk of cardiovascular disease and cancer in later life: systematic review and meta-analysis. *BMJ*. 2007;335:974. doi: 10.1136/bmj.39335.385301.BE
28. Crump C, Sundquist J, McLaughlin MA, Dolan SM, Govindarajulu U, Sieh W, Sundquist K. Adverse pregnancy outcomes and long term risk of ischemic heart disease in mothers: national cohort and co-sibling study. *BMJ*. 2023;380:e072112. doi: 10.1136/bmj-2022-072112
29. Perelshtein Brezinov O, Klempfner R, Zekry SB, Goldenberg I, Kuperstein R. Prognostic value of ejection fraction in patients admitted with acute coronary syndrome. *Medicine (Baltimore)*. 2017;96:e6226. doi: 10.1097/MD.0000000000006226
30. Lansky AJ, Goto K, Cristea E, Fahy M, Parise H, Feit F, Ohman EM, White HD, Alexander KP, Bertrand ME, et al. Clinical and angiographic predictors of short- and long-term ischemic events in acute coronary syndromes. *Circ Cardiovasc Interv*. 2010;3:308–316. doi: 10.1161/CIRCINTERVENTIONS.109.887604

31. Bosch X, Théroux P. Left ventricular ejection fraction to predict early mortality in patients with non–ST-segment elevation acute coronary syndromes. *Am Heart J*. 2005;150:215–220. doi: 10.1016/j.ahj.2004.09.027
32. Redfors B, Angerås O, Råmunddal T, Dworeck C, Haraldsson I, Ioanes D, Petursson P, Libungan B, Odenstedt J, Stewart J, et al. 17-Year trends in incidence and prognosis of cardiogenic shock in patients with acute myocardial infarction in western Sweden. *Int J Cardiol*. 2015;185:256–262. doi: 10.1016/j.ijcard.2015.03.106
33. Bhatt DL, Lopes RD, Harrington RA. Diagnosis and treatment of acute coronary syndromes: a review. *JAMA*. 2022;327:662–675. doi: 10.1001/jama.2022.0358
34. Handmark M, Lin A, Edsfeldt A, Sarno G, Fraser A, Rich-Edwards JW, Gonçalves I, Pihlsgård M, Timpka S. STEMI, revascularization, and peak troponin by adverse pregnancy outcomes in women with myocardial infarction. *JACC Adv*. 2024;3:101088. doi: 10.1016/j.jacadv.2024.101088
35. Simonsson M, Winell H, Olsson H, Szummer K, Alfredsson J, Hall M, Dondo TB, Gale CP, Jernberg T. Development and validation of a novel risk score for in-hospital major bleeding in acute myocardial infarction:—the SWEDEHEART score. *J Am Heart Assoc*. 2019;8:e012157. doi: 10.1161/JAHA.119.012157
36. Gard A, Lindahl B, Batra G, Hjort M, Szummer K, Baron T. Diagnosing type 2 myocardial infarction in clinical routine. A validation study. *Scand Cardiovasc J*. 2019;53:259–265. doi: 10.1080/14017431.2019.1638961
37. Rosvall M, Ohlsson H, Hansen O, Chaix B, Merlo J. Auditing patient registration in the Swedish quality register for acute coronary syndrome. *Scand J Public Health*. 2010;38:533–540. doi: 10.1177/1403494810365109
38. Brouwers L, van der Meiden-van Roest AJ, Savelkoul C, Vogelvang TE, Lely AT, Franx A, van Rijn BB. Recurrence of pre-eclampsia and the risk of future hypertension and cardiovascular disease: a systematic review and meta-analysis. *BJOG*. 2018;125:1642–1654. doi: 10.1111/1471-0528.15394
39. Ramsay JE, Stewart F, Greer IA, Sattar N. Microvascular dysfunction: a link between pre-eclampsia and maternal coronary heart disease. *BJOG*. 2003;110:1029–1031. doi: https://doi.org/10.1111/j.1471-0528.2003.02069.x
40. Yang C, Baker PN, Granger JP, Davidge ST, Tong C. Long-term impacts of preeclampsia on the cardiovascular system of mother and offspring. *Hypertension*. 2023;80:1821–1833. doi: 10.1161/HYPERTENSIONAHA.123.21061
41. Garrido-Gimenez C, Mendoza M, Cruz-Lemini M, Galian-Gay L, Sanchez-Garcia O, Granato C, Rodriguez-Sureda V, Rodriguez-Palomares J, Carreras-Moratonas E, Cabero-Roura L, et al. Angiogenic factors and long-term cardiovascular risk in women that developed preeclampsia during pregnancy. *Hypertension*. 2020;76:1808–1816. doi: 10.1161/HYPERTENSIONAHA.120.15830
42. Vakili BA, Kaplan RC, Brown DL. Sex-based differences in early mortality of patients undergoing primary angioplasty for first acute myocardial infarction. *Circulation*. 2001;104:3034–3038. doi: 10.1161/hc5001.101060
43. Sambola A, Elola FJ, Buera I, Fernández C, Bernal JL, Ariza A, Brindis R, Bueno H, Rodríguez-Padial L, Marín F, et al. Sex bias in admission to tertiary-care centres for acute myocardial infarction and cardiogenic shock. *Eur J Clin Invest*. 2021;51:e13526. doi: 10.1111/eci.13526
44. Isorni MA, Aissaoui N, Angoulvant D, Bonello L, Lemesle G, Delmas C, Henry P, Schiele F, Ferrières J, Simon T, et al; FAST-MI Investigators. Temporal trends in clinical characteristics and management according to sex in patients with cardiogenic shock after acute myocardial infarction: the FAST-MI programme. *Arch Cardiovasc Dis*. 2018;111:555–563. doi: 10.1016/j.acvd.2018.01.002
45. Epps KC, Tehrani BN, Rosner C, Bagchi P, Cotugno A, Damluji AA, deFilippi C, Desai S, Ibrahim N, Psotka M, et al. Sex-related differences in patient characteristics, hemodynamics, and outcomes of cardiogenic shock: INOVA-SHOCK registry. *J Soc Cardiovasc Angiogr Interv*. 2023;2:100978. doi: 10.1016/j.jscai.2023.100978
46. Mas-Llado C, Gonzalez-Del-Hoyo M, Siquier-Padilla J, Blaya-Peña L, Coughlan JJ, García de la Villa B, Peral V, Rossello X. Representativeness in randomised clinical trials supporting acute coronary syndrome guidelines. *Eur Heart J Qual Care Clin Outcomes*. 2023;9:796–805. doi: 10.1093/ehjqcco/qcad007
47. Hausvater A, Giannone T, Sandoval YHG, Doonan RJ, Antonopoulos CN, Matsoukis IL, Petridou ET, Daskalopoulou SS. The association between preeclampsia and arterial stiffness. *J Hypertens*. 2012;30:17–33. doi: 10.1097/HJH.0b013e32834e4b0f
48. Duley L, Meher S, Hunter KE, Seidler AL, Askie LM. Antiplatelet agents for preventing pre-eclampsia and its complications. *Cochrane Database Syst Rev*. 2019;2019:CD004659. doi: 10.1002/14651858.CD004659.pub3
49. Hubel CA, Powers RW, Snaedal S, Gammill HS, Ness RB, Roberts JM, Arngrímsson R. C-reactive protein is elevated 30 years after eclamptic pregnancy. *Hypertension*. 2008;51:1499–1505. doi: 10.1161/HYPERTENSIONAHA.108.109934
50. Melchiorre K, Sutherland G, Sharma R, Nanni M, Thilaganathan B. Mid-gestational maternal cardiovascular profile in preterm and term pre-eclampsia: a prospective study. *BJOG*. 2013;120:496–504. doi: 10.1111/1471-0528.12068
51. Behrens I, Basit S, Melbye M, Lykke JA, Wohlfahrt J, Bundgaard H, Thilaganathan B, Boyd HA. Risk of post-pregnancy hypertension in women with a history of hypertensive disorders of pregnancy: nationwide cohort study. *BMJ*. 2017;358:j3078. doi: 10.1136/bmj.j3078
52. Boucheron P, Lailler G, Moutengou E, Regnault N, Gabet A, Deneux-Tharaux C, Kretz S, Grave C, Mounier-Vehier C, Tsatsaris V, et al. Hypertensive disorders of pregnancy and onset of chronic hypertension in France: the nationwide CONCEPTION study. *Eur Heart J*. 2022;43:3352–3361. doi: 10.1093/eurheartj/ehab686
53. Kitt J, Fox R, Frost A, Shanyinde M, Tucker K, Bateman PA, Suriano K, Kenworthy Y, McCourt A, Woodward W, et al. Long-term blood pressure control after hypertensive pregnancy following physician-optimized self-management: the POP-HT randomized clinical trial. *JAMA*. 2023;330:1991–1999. doi: 10.1001/jama.2023.21523
54. Cairns AE, Tucker KL, Leeson P, Mackillop LH, Santos M, Velardo C, Salvi D, Mort S, Mollison J, Tarassenko L, et al; SNAP-HT Investigators. Self-management of postnatal hypertension: the SNAP-HT trial. *Hypertension*. 2018;72:425–432. doi: 10.1161/HYPERTENSIONAHA.118.10911
55. Dall'Asta A, D'Antonio F, Saccone G, Buca D, Mastantuoni E, Liberati M, Flacco ME, Frusca T, Ghi T. Cardiovascular events following pregnancy complicated by pre-eclampsia with emphasis on comparison between early- and late-onset forms: systematic review and meta-analysis. *Ultrasound Obstet Gynecol*. 2021;57:698–709. doi: 10.1002/uog.22107
56. Parikh NI, Gonzalez JM, Anderson CAM, Judd SE, Rexrode KM, Hlatky MA, Gunderson EP, Stuart JJ, Vaidya D; American Heart Association Council on Epidemiology and Prevention; Council on Arteriosclerosis, Thrombosis and Vascular Biology; Council on Cardiovascular and Stroke Nursing; and the Stroke Council. Adverse pregnancy outcomes and cardiovascular disease risk: unique opportunities for cardiovascular disease prevention in women: a scientific statement from the American Heart Association. *Circulation*. 2021;143:e902–e916. doi: 10.1161/CIR.0000000000000961
57. Miller EC, Boehme AK, Chung NT, Wang SS, Lacey JV, Lakshminarayan K, Zhong C, Woo D, Bello NA, Wapner R, et al. Aspirin reduces long-term stroke risk in women with prior hypertensive disorders of pregnancy. *Neurology*. 2019;92:e305–e316. doi: 10.1212/WNL.0000000000006815
58. Gamble DT, Brikinns B, Myint PK, Bhattacharya S. Hypertensive disorders of pregnancy and subsequent cardiovascular disease: current national and international guidelines and the need for future research. *Front Cardiovasc Med*. 2019;6:55. doi: 10.3389/fcvm.2019.00055
59. McEvoy JW. 2024 ESC guidelines for the management of elevated blood pressure and hypertension. *Eur Heart J*. 2024;45:3912–4018. doi: 10.1093/eurheartj/ehae178. Accessed January 9, 2025. https://academic.oup.com/eurheartj/article/45/38/3912/7741010