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Hypertensive disorders of pregnancy and onset of chronic hypertension in France: the nationwide CONCEPTION study

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Aims Hypertensive disorders of pregnancy (HDP) are a leading cause of maternal and foetal morbidity and mortality. We aimed to estimate the impact of HDP on the onset of chronic hypertension in primiparous women in the first years following childbirth.

Methods and results This nationwide cohort study used data from the French National Health Data System (SNDS). All eligible primiparous women without pre-existing chronic hypertension who delivered between 2010 and 2018 were included. Women were followed up from six weeks post-partum until onset of hypertension, a cardiovascular event, death, or the study end date (31 December 2018). The main outcome was a diagnosis of chronic hypertension. We used Cox models to estimate hazard ratios (HRs) of chronic hypertension for all types of HDP. Overall, 2 663 573 women were included with a mean follow-up time of 3.0 years. Among them, 180 063 (6.73%) had an HDP. Specifically 66 260 (2.16%) had pre-eclampsia (PE) and 113 803 (4.27%) had gestational hypertension (GH). Compared with women who had no HDP, the fully adjusted HRs of chronic hypertension were 6.03 [95% confidence interval (CI) 5.89–6.17] for GH, 8.10 (95% CI 7.88–8.33) for PE (all sorts), 12.95 (95% CI 12.29–13.65) for early PE, 9.90 (95% CI 9.53–10.28) for severe PE, and 13.17 (95% CI 12.74–13.60) for PE following GH. Hypertensive disorders of pregnancy exposure duration was an additional risk factor of chronic hypertension for all PE subgroups. Women with HDP consulted a general practitioner or cardiologist more frequently and earlier.

Conclusion Hypertensive disorders of pregnancy exposure greatly increased the risk of chronic hypertension in the first years following delivery.

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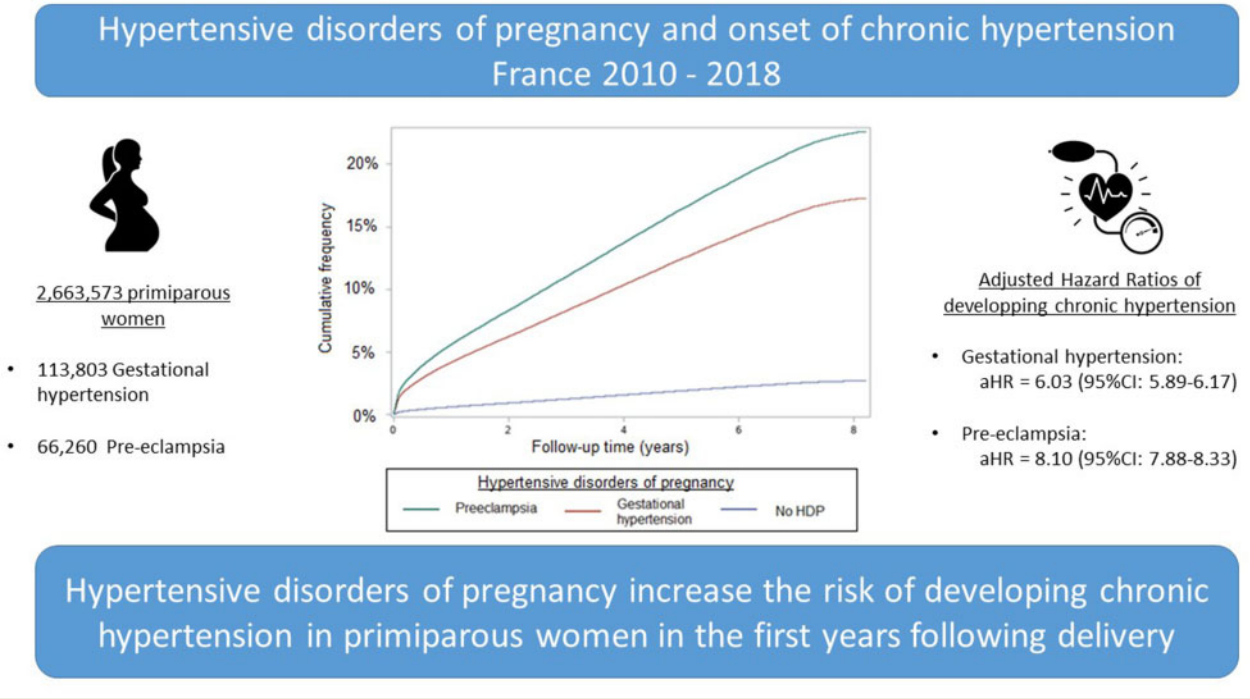
Graphical Abstract



Keywords Pre-eclampsia • Gestational hypertension • Hypertension • Blood pressure • Epidemiology • Pregnancy complication

Translational perspective

Hypertensive disorders of pregnancy (HDP) represent a major cause of maternal morbidity. Women with gestational hypertension (GH) or pre-eclampsia (PE) are more likely to develop chronic hypertension. This risk is even greater for women with early PE, severe PE, or PE following GH. Hypertensive disorders of pregnancy exposure duration is an additional risk factor of chronic hypertension for PE, but this effect remains unclear for GH. To adequately screen for hypertension and prevent associated complications, patients with HDP and attending physicians should be made more aware of the importance of follow-up.

Introduction

Hypertensive disorders of pregnancy (HDP)—defined as pre-existing chronic hypertension, gestational hypertension (GH), and pre-eclampsia (PE)/eclampsia—constitute a global public health issue which is insufficiently tackled.[1] They are the main cause of maternal morbidity during pregnancy and following childbirth in industrialized countries.[2] Hypertensive disorders of pregnancy prevalence in pregnant women is estimated to be between 5% and 10%, and believed to impact primiparous women more often than their multiparous counterparts.[1] A recent large-scale study of pregnant women in France, using data from the National Health Data System (SNDS), estimated an age-standardized HDP prevalence of 7.4% (9.1% and 6.3% in primiparous and multiparous women, respectively), and observed an upward trend in HDP prevalence due to older age at first childbirth and rising prevalence of obesity.[3]

In the long term, HDP are associated with an increased risk of chronic hypertension and cardiovascular or renal events.[4–11] However, little is known about the short-term impact of HDP on these outcomes. In a population-based study, Ray *et al.*[12] reported that the risk of cardiovascular disease was higher after a maternal placental syndrome but did not assess the onset of hypertension. A single-centre study by Black *et al.*[13] found that women with HDP were 2.36 [95% confidence interval (CI) 1.97–2.83] and 2.48 (95% CI 1.99–3.11) times more likely to develop pre-hypertension and hypertension in the year after delivery. To the best of our knowledge, the impact of the exposure duration of HDP on the early onset of chronic hypertension has not been assessed, nor have the different

configurations of PE (early PE, severe PE, PE following GH). In this context, we aimed to estimate the impact of different types of HDP on the early onset (i.e. first years after delivery) of chronic hypertension in women in France, and to assess the medical follow-up of women with a history of HDP.

Methods

Data source

The CONCEPTION (Cohort of Cardiovascular Diseases in Pregnancy) study is a prospective cohort designed to study hypertensive disorder and cardiovascular event epidemiology in French women who gave birth, using data from the French National Health Insurance Information System database (*Système National des Données de Santé*, or SNDS).[14] This database contains comprehensive information on all healthcare expenditures reimbursed by the national health insurance system for the entire French population (~66 000 000 people). It comprises two information sources: the National Hospital Discharge Database (PMSI), which records information on public and private hospital stays—including diagnoses—under ICD-10 codes, and the Interscheme Consumption Data Mart (DCIR), which records information on out-of-hospital care. More specifically, the DCIR contains reimbursements of healthcare expenditures (e.g. medicines, outpatient medical care).

Study population

All first deliveries of women included in CONCEPTION (hereafter referred as primiparous women) were eligible for the present analysis. The cohort population is described in detail elsewhere. Briefly, the national health insurance general scheme and mutual insurance companies (which provide complementary healthcare insurance cover) combined cover ~90% of the population in France. Of those covered, all primiparous women who gave birth in a hospital after 22 weeks of gestation between 1 January 2010 and 31 December 2018 were eligible for inclusion in CONCEPTION. Women with missing data in their medical history, those aged under 15 or over 49 years, those with a multiple pregnancy, and those with a history of cardiovascular events, end-stage renal disease, cardiac malformation, inflammatory disease, HIV before delivery, or chronic hypertension before pregnancy, were all excluded. Follow-up started 6 weeks after childbirth and ended either when hypertension occurred, when the woman died, when a second pregnancy occurred, or at the study end date (31 December 2018), whichever came first.

Exposure to hypertensive disorders of pregnancy

We used different algorithms to identify HDP in the SNDS, based on antihypertensive drug delivery and diagnoses of HDP during hospital stays.

Gestational hypertension was defined as having at least one delivery of antihypertensive drugs between 20 weeks of gestation and 6 weeks postpartum, or a hospital stay with a diagnosis of GH (ICD-10 code O13). To avoid potential misclassification, women who were reimbursed for antihypertensive drugs and were hospitalized with preterm labour as primary diagnosis (ICD10 codes O47, O60.0-O60.2, O60.9) were excluded from the GH group, as the antihypertensive treatment may have been prescribed for preterm labour.

Pre-eclampsia, eclampsia, and HELLP syndrome were identified from diagnoses in hospital stays (ICD-10 codes O14, O15, and 014.2, respectively). We considered PE to be severe when diagnosed during hospitalization (ICD-10 code 014.1), or when eclampsia or HELLP syndrome were diagnosed. For all other situations, it was considered simple. Pre-eclampsia occurring before 34 weeks of gestation was defined as early onset PE. GH followed by PE was classified in the 'PE following GH' subgroup. Pre-eclampsia with foetal growth restriction was defined by a birth weight inferior to the tenth percentile for gestational age and sex. HDP exposure duration was calculated as the number of days between HDP (any type) diagnosis and childbirth.

Outcomes

Chronic hypertension was identified by at least three refunds for antihypertensive drugs on different dates over a 12-month period, or on two dates if at least one large pack (90 pills) of antihypertensive drugs was dispensed. We considered the date of first drug delivery to be the date of chronic hypertension diagnosis.

Covariates

Sociodemographic data and medical history of the women included in the study, as well as information related to their pregnancy, post-partum period, and healthcare management, were all taken from the SNDS. Delivery mode (e.g. caesarean section), intrauterine foetal death, obesity (ICD-10 I66), and pregnancy-related haemorrhaging were identified from hospital records. Tobacco use was identified using an algorithm combining specific hospital coding and delivery of prescribed nicotine replacement therapy before or during pregnancy. A history of cardiovascular events and end-stage renal disease was identified in hospital records from 2006 onwards using the following ICD-10 codes: I20.0 and I21–I23 for acute coronary syndrome, I60–I64 for stroke, I50 for heart failure, I26 for thromboembolic disease, and both O225 and O873 for cerebral thrombosis. Pre-existing diabetes was identified using an algorithm based on delivery of three antidiabetic drugs on three different dates in the year preceding pregnancy (or on two dates if at least one large package of antidiabetic drugs was delivered). Gestational diabetes was identified using an algorithm combining the delivery of insulin and glucose strips, or a diagnosis of diabetes during pregnancy with no pre-existing diabetes. Persons who benefitted from Universal Medical Coverage (CMUc)—a social benefit in France for those whose income is below a certain ceiling—were defined as living in social deprivation. All outpatient visits with a general practitioner, a cardiologist, a neurologist, a nephrologist, an endocrinologist, a gynaecologist, or a midwife were identified from one year before pregnancy until the end of follow-up.

Statistical analysis

We described the study population characteristics, follow-up time, and healthcare management, and computed a cumulative incidence curve for chronic hypertension stratified by type of HDP. Crude prevalence was then calculated for each type of HDP. Crude and adjusted hazard ratios (HR and aHR) with 95% CI for the development of chronic hypertension in women presenting each type of HDP—compared with women without any HDP—were estimated using Cox models. The latter were both non-adjusted and adjusted for the following confounders: year of childbirth, duration of HDP exposure, maternal age, social deprivation, gestational diabetes, obesity, tobacco use, and pre-existing diabetes. For the PE with foetal growth restriction subgroup, the analysis was restricted to childbirths between 2013 and 2018 because birth weight was not recorded in the SNDS before 2013. For each type of HDP, the same univariate and multivariate Cox models were performed with a natural spline on the exposure duration (3 nodes) to HDP in weeks to account for the non-linear effect of this continuous variable on the onset of chronic hypertension. From these splines, we plotted the continuous HRs for the onset of chronic hypertension according to the exposure duration to HDP. These HRs were displayed from 0 to 10 weeks of exposure for PE and from 0 to 20 weeks for GH as these periods comprised >99% of the

exposure durations in these populations. In order to better distinguish the specific effects of early PE and exposure duration to PE, we estimated HRs for the development of chronic hypertension in women with early PE compared to women with late PE, using Cox models (unadjusted, adjusted on covariates, and adjusted on exposure duration to PE and covariates).

Results

The present analysis included 2 663 573 women participating in the CONCEPTION cohort for the period 1 January 2010 to 31 December 2018 (*Figure 1*). *Table 1* presents their characteristics, according to the type of HDP diagnosed. Mean follow-up time was 3.0 years (interquartile range 1.3–4.2). Those with a history of HDP were older and had a lower gestational age at childbirth than those with no HDP history. The former were more likely to be obese, to live in social deprivation, and to have had pre-existing or gestational diabetes, a caesarean section, intrauterine foetal death, and/or haemorrhaging during pregnancy. During follow-up, 47 533 (1.78%) women developed chronic hypertension. Women with HDP were more likely to develop it (8.69% and 10.84% of those with GH and PE, respectively) than women with no HDP (1.23%). In the former group, the mean duration of exposure to HDP was 35.8 days for GH and 7.8 days for PE.

Table 2 shows the crude prevalence of all types of HDP. Overall, 180 063 women (6.76%) were diagnosed with HDP during their pregnancy, specifically 113 803 women (4.27%) with GH and 66 260 women (2.49%) with PE. Among the latter, 11 666 (17.61%) had early onset PE, 26 921 (40.62%) had severe PE, and 8665 (13.08%) had PE following GH.

The cumulative incidence curves (*Figure 2*) showed that the onset of chronic hypertension was faster in women diagnosed with GH or PE than in those with no HDP. *Table 3* presents time-to-event analysis results according to type of HDP. Women with a history of HDP had a higher risk of chronic hypertension than those without HDP [aHR 6.77 (95% CI 6.64–6.90); $P < 0.0001$]. This risk was slightly higher for those with PE [aHR 8.10 (95% CI 7.88–8.33), $P < 0.0001$] than for those with GH [aHR 6.03 (95% CI 5.89–6.17), $P < 0.0001$]. When compared to women with no HDP, the adjusted HRs of developing chronic hypertension were 9.90 (95% CI 9.53–10.28) for women with severe PE, 12.95 (95% CI 12.29–13.65) for women with early PE, 13.17 (95% CI 12.74–13.60) for women with PE following GH, and 12.49 (95% CI 11.76–13.27) for women with PE with foetal growth restriction. Complete outputs of the models are shown in Supplementary Material 1.

The Cox models with a natural spline on the exposure duration to HDPs showed that the adjusted HRs of developing chronic hypertension significantly and continuously increased with exposure duration to PE (*Figure 3*). This effect was greater for severe PE and for PE with foetal growth restriction, whereas for GH, this relation was fluctuating and of low magnitude.

When compared to late PE, early-onset PE was associated with an increased risk of chronic hypertension in both the unadjusted [HR 1.92 (95% CI 1.83–2.02), $P < 0.0001$] and adjusted [aHR 1.80 (95% CI 1.71–1.90), $P < 0.0001$] models. When the HDP exposure duration was taken into account, the association of chronic hypertension with early-onset PE persisted but was attenuated [aHR 1.69 (95% CI 1.61–1.79), $P < 0.0001$] (*Figure 4*).

Supplementary Material 2 displays consultation patterns of women according to type of HDP. During the first year following delivery, 2 198 194 (82.5%) women visited a general practitioner, 30 343 (1.1%) a cardiologist, 1 519 700 (57.1%) a gynaecologist or a midwife, and 116 510 (4.4%) a physician from another specialty (i.e. neurologist, endocrinologist, nephrologist). At the end of follow-up, these figures were, respectively, 2 457 109 (92.2%), 112 760 (4.2%), 2 010 689 (75.5%), and 233 702 (8.8%). Median time to first visit was ∼2 months for a general practitioner and gynaecologist or midwife (64 and 53 days, respectively), 717 days for a cardiologist, and 343 days for a physician from another specialty. Women diagnosed with PE visited a gynaecologist or a midwife less often and later than those with no PE ($P < 0.0001$). However, women with a history of HDP, and especially former PE women, visited physicians with other specialties more often and earlier than those without HDP (all $P < 0.0001$).

Discussion

Main findings

This large-scale nationwide prospective cohort of 2 663 573 primiparous women in France enabled us to accurately estimate chronic hypertension onset according to various types of HDP. We found that the risk of chronic hypertension increased dramatically and rapidly in the years following delivery in women who developed GH (aHR 6.03) or PE (aHR 8.10) (*Graphical abstract*). This risk was even greater in women with early PE, severe PE, or PE following GH. While the duration of PE was a risk factor of chronic hypertension, this effect was unclear for GH. We also found that women with a history of HDP, and especially former PE women, visited physicians more often and earlier than those without HDP.

Interpretation

One interesting finding of the present analysis is that while GH is a less severe hypertensive disorder than PE, they were both associated with similarly high risks of developing chronic hypertension. Many previous studies have clearly shown that women with a history of HDP, in particular PE, have an increased risk of developing chronic hypertension and cardiovascular diseases.[8,15,16] Some authors have more specifically studied early PE or PE with foetal growth restriction and have demonstrated a further increased risk.[17] Fewer authors have focused their reports on GH without PE. Several risk factors for HDP, for example, family history of hypertension, obesity, and diabetes are also risk factors for chronic hypertension outside pregnancy. It remains unclear whether these shared risk factors explain both the occurrence of HDP and the subsequent chronic hypertension, or if HDP generates, with a causal relationship, chronic hypertension.[18] Given that our models were adjusted for the main risk factors of hypertension onset, including obesity and cardio-metabolic history, the latter hypothesis appears to be the most likely. Moreover, we found a significant relationship between the duration of exposure to PE and the subsequent occurrence of chronic hypertension. To the best of our knowledge, this result has never previously been reported, unlike the effects of severe or early PE.[19,20] This increased risk of chronic hypertension, depending on the duration of

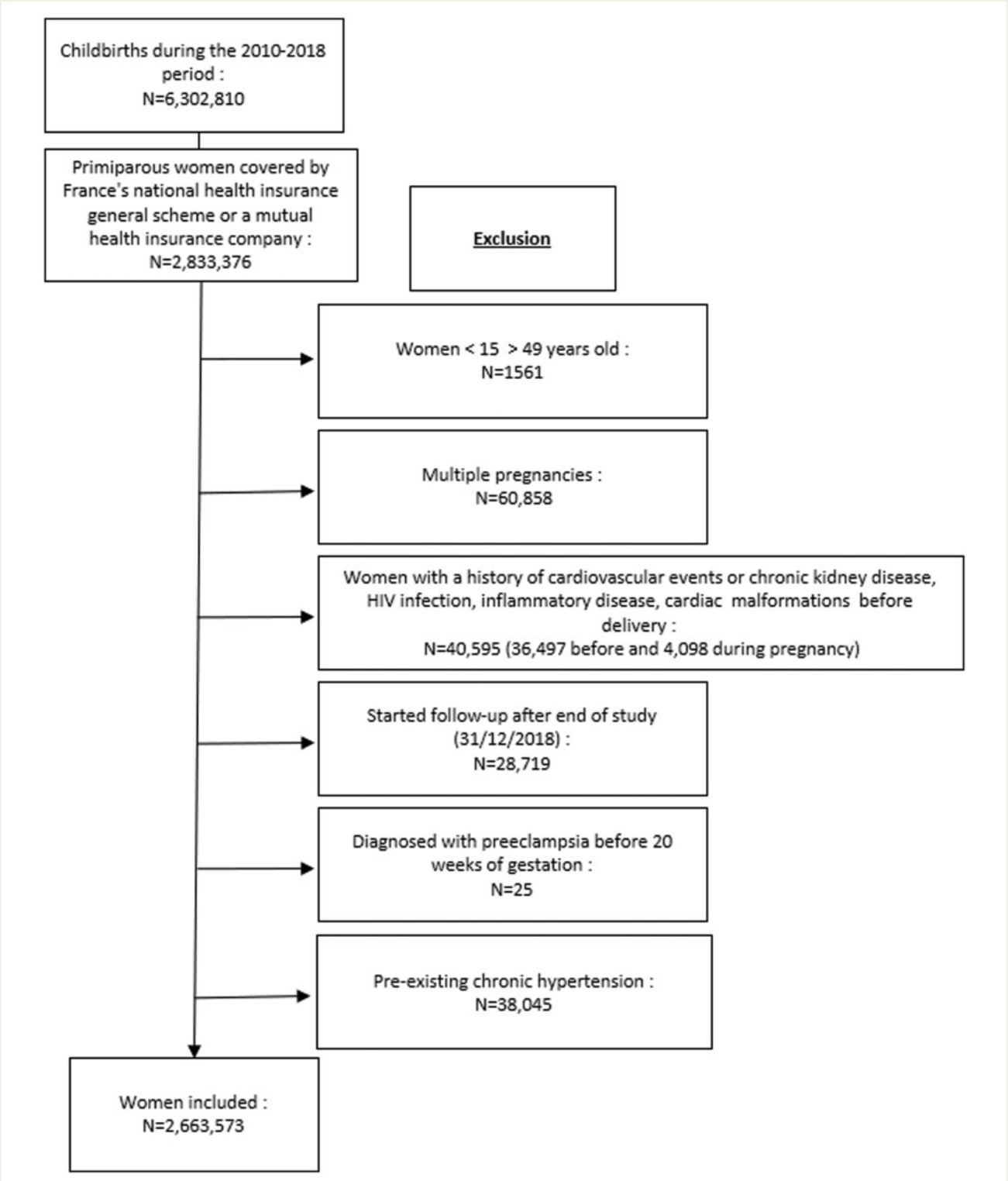


Figure 1 Flowchart of study participants.

exposure to PE, would rather be in favour of a vascular toxicity of pathophysiological phenomena linked to PE. Without prejudging the pathophysiological mechanisms that were not accessed in our study, we can hypothesize that the vascular damages induced by PE directly and quantitatively contribute to the future development of chronic hypertension. Indeed, Pruthi *et al.*[21] reported that after vessel injury, PE-exposed mice had significantly enhanced vascular remodelling with increased vascular smooth muscle cell proliferation and vessel

Table 1 Population characteristics by type of hypertensive disorder of pregnancy

	Total		Hypertensive disorders					
			No HDP		Gestational hypertension		Pre-eclampsia	
	N	% or mean (SD)	*N*	% or mean (SD)	*N*	% or mean (SD)	*N*	% or mean (SD)
Sociodemographic characteristics								
Maternal age (years)	2 663 573	28.17 (5.32)	2 483 510	28.12 (5.29)	113 803	28.79 (5.70)	66 260	28.95 (5.86)
Social deprivation[a]	367 841	13.81	341 343	13.74	15 655	13.76	10 843	16.36
Cardiovascular risk factors								
Obesity	103 617	3.89	88 719	3.57	7803	6.86	7095	10.71
Pre-existing diabetes	11 631	0.44	9633	0.39	969	0.85	1029	1.55
Tobacco	233 940	8.78	218 434	8.8	10 046	8.83	5460	8.24
Pregnancy characteristics and outcomes								
Gestational age (weeks)	2 663 573	39.04 (2.13)	2 483 510	39.12 (2.05)	113 803	38.88 (1.85)	66 260	36.42 (3.57)
Caesarean section	679 847	25.52	600 611	24.18	38 443	33.78	40 793	61.57
Intrauterine foetal death	1009	0.04	880	0.04	58	0.05	71	0.11
Gestational diabetes	216 676	8.13	196 293	7.9	12 454	10.94	7929	11.97
Haemorrhaging during pregnancy	22 436	0.84	20 352	0.82	1362	1.2	722	1.09
HDP exposure duration (days)	2 663 573	NA	2 483 510	0.00	113 803	35.85 (37.94)	66 260	7.87 (17.26)

HDP, hypertensive disorder of pregnancy; NA, not available; SD, standard deviation.
[a]Persons who benefitted from Universal Medical Coverage (CMUc), a social benefit in France for those whose income is below a certain ceiling, were defined as living in Social Deprivation.

fibrosis compared to control pregnancy. These data support a model in which vessels exposed to PE quantitatively retain a persistently enhanced vascular response to injury.

Gestational hypertension followed by PE is rarely reported in the international literature and is often included in the PE group. The statistical power of our study allowed us to study this specific type of HDP ($n = 8865$) and to show that it was associated with the greatest risk of developing chronic hypertension. One possible explanation for this result could be that vascular sequelae of GH on the one hand and PE on the other lead to different and potentially additive risks of developing chronic hypertension. This supports the previously described theory[22] that GH and PE share a common pathophysiological pathway—resulting from hypoperfusion and placental ischaemia—that leads to the release of anti-angiogenic and inflammatory molecules. These molecules generate an endothelial dysfunction, which alters arterial haemodynamics, notably by reducing vascular compliance.[22] Moreover, there may have been some misclassification of women with undiagnosed or untreated chronic hypertension in the GH group. This is even more probable in the 'PE following GH' group because of the link between chronic hypertension and PE. Finally, after adjustment for duration of exposure, the persistent but attenuated risk of chronic hypertension in women with early-onset PE compared with those who had late PE (from 1.84 to 1.63) suggests that both early-onset PE and duration of PE exposure have independent effects.

To avoid a delayed diagnosis of chronic complications of HDP, French national healthcare management guidelines recommend that women with a history of HDP see a physician after childbirth. If a complication is diagnosed, they may receive appropriate healthcare to prevent early onset of potential cardiovascular or renal events.[23] According to the guidelines of the European Society of Cardiology and the European Society of Hypertension, annual visits to primary care physician to check blood pressure and metabolic factors are recommended for women who developed GH or PE.[24,25] In the present study, although women with HDP consulted more frequently and earlier than those with no HDP, their healthcare management was not optimal. Moreover, women with a history of PE consulted a physician more frequently and earlier than those with a history of GH. However, both groups had quite a similar risk of developing chronic hypertension. To adequately screen for hypertension and prevent associated

Table 2 Crude prevalence of hypertensive disorders of pregnancy

Hypertensive disorders of pregnancy	*N*	Crude prevalence (%)
No hypertensive disorder of pregnancy	2 483 510	93.24
Gestational hypertension	113 803	4.27
Pre-eclampsia (total)	66 260	2.49
Pre-eclampsia following gestational hypertension	8665	0.33
Early pre-eclampsia	11 666	0.44
'Simple' pre-eclampsia[a]	39 339	1.48
Severe pre-eclampsia	26 921	1.01

[a]'Simple' refers to pregnant women with pre-eclampsia which was neither early- or late-onset pre-eclampsia and which was not associated with foetal growth restriction.

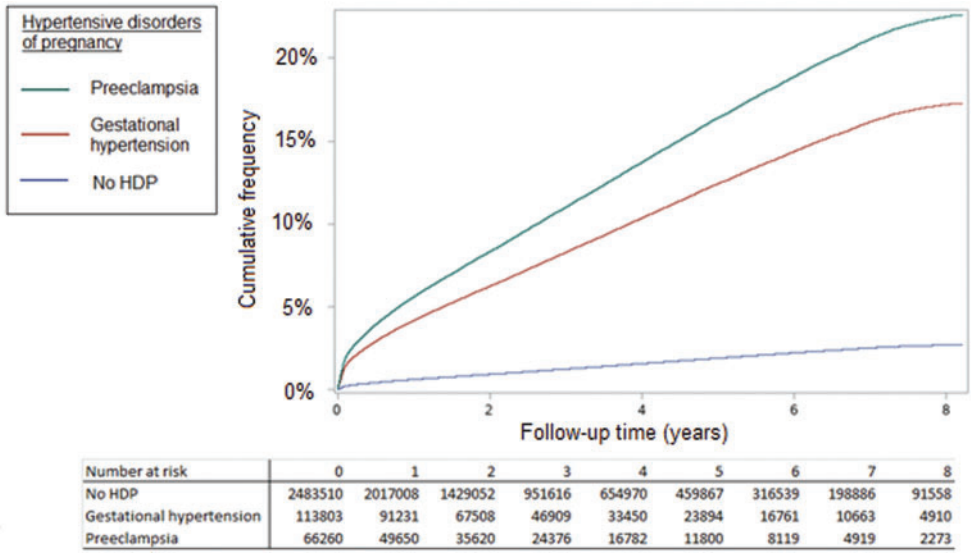


Figure 2 Cumulative incidence of chronic hypertension following childbirth according to type of hypertensive disorder of pregnancy. 'At risk' means that the subject did not have an event before time *t*, and was not censored before or at time *t*. HDP, hypertensive disorder of pregnancy.

Table 3 Hazard ratios of hypertensive disorders of pregnancy in unadjusted and adjusted Cox regression models explaining the onset of persistent hypertension

		N	Unadjusted Cox models			Fully adjusted[a] Cox models		
			HR	95% CI	*P*-value	HR[1]	95% CI	*P*-value
Any type of HDP	No	2 483 510	Ref	—	—	Ref	—	—
	Yes	180 063	7.75	7.60–7.90	<0.0001	6.77	6.64–6.90	<0.0001
GH alone	No	2 483 510	Ref	—	—	Ref	—	—
	Yes	113 803	6.88	6.72–7.04	<0.0001	6.03	5.89–6.17	<0.0001
Any type of pre-eclampsia	No	2 483 510	Ref	—	—	Ref	—	—
	Yes	66 260	9.34	9.10–9.59	<0.0001	8.10	7.88–8.33	<0.0001
GH with superimposed pre-eclampsia	No	2 483 510	Ref	—	—	Ref	—	—
	Yes	8665	15.93	15.45–16.43	<0.0001	13.17	12.74–13.60	<0.0001
Severe pre-eclampsia	No	1 571 891	Ref	—	—	Ref	—	—
	Yes	17 026	11.55	11.13–11.98	<0.0001	9.90	9.53–10.28	<0.0001
Early pre-eclampsia	No	1 571 891	Ref	—	—	Ref	—	—
	Yes	7455	15.77	15.02–16.56	<0.0001	12.95	12.29–13.65	<0.0001
Pre-eclampsia with foetal growth restriction[b]	No	1 571 891	Ref	—	—	Ref	—	—
	Yes	14 271	14.37	13.55–15.25	<0.0001	12.49	11.76–13.27	<0.0001

CI, confidence interval; GH, gestational hypertension; HDP, hypertensive disorder of pregnancy; HR, hazard ratio; Ref, reference.
[a]Adjusted on year of delivery, maternal age, social deprivation, gestational diabetes, obesity, tobacco and history of diabetes.
[b]Based on deliveries during the period 2013–2018.

complications, patients with HDP and attending physicians should be made more aware of the importance of follow-up.

Strengths

The main strength of this study is its nationwide design. This was made possible by the use of data from the SNDS, a national medico-administrative database with near-exhaustive data for hospital records, which provides great accuracy when identifying pregnancies in France (99.6% of all births in France are reported in the SNDS). The comprehensiveness of the data on our study population and on their health expenditures (including antihypertensive drug delivery) ensured optimal statistical power to obtain precise estimates for each type of HDP, and to perform subgroup analyses. Furthermore, our decision to assume that antihypertensive drug delivery was a

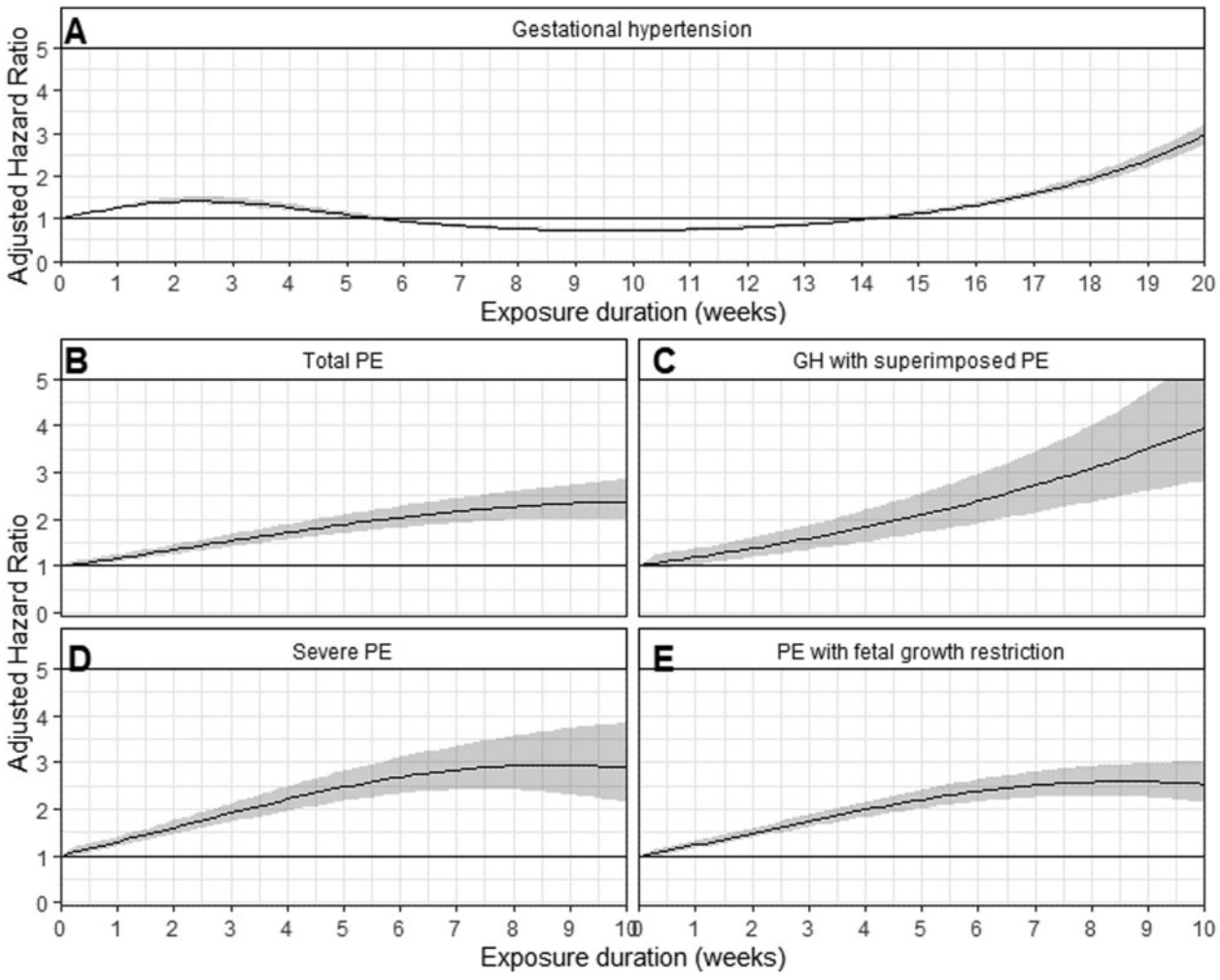


Figure 3 Hazard ratios of developing chronic hypertension according to exposure duration of hypertensive disorders of pregnancy (**A–E**). Hazards ratios modelled with Cox regression models with a natural spline on the exposure duration, adjusted on year of delivery, maternal age, social deprivation, gestational diabetes, obesity, tobacco, and history of diabetes (the reference modality for hazard ratios is an exposure duration of 0 week). Gray stripes represent the 95% confidence interval of the hazard ratios. PE, pre-eclampsia.

proxy for the diagnosis of chronic hypertension probably underestimates the true prevalence of this condition in post-partum women in France. Finally, by studying the impact of the exposure duration for each type of HDP, we were able to acquire a greater understanding of the mechanisms behind the increased risk of chronic hypertension in this population.

Limitations

As we identified hypertension only by refunds of antihypertensive drugs, the proportion of women who develop hypertension is probably underestimated. However, this ranking bias is probably not differential between women who developed HDP and those who did not. A previous evaluation of algorithms used to identify GH and PE showed that physicians may decide not to treat women with non-severe GH (i.e. <160/110 mmHg). Consequently, untreated moderate GH not reported during hospitalization could have been missed, and therefore GH underestimated. Furthermore, misclassifying women with moderate GH in the group of women without HDP (reference) may have led to an underestimation of the risk of chronic hypertension in all HDP groups. In addition, we cannot exclude residual confounding, especially concerning obesity, a major risk factor of chronic hypertension.[26] Indeed, we may have underestimated the prevalence of obesity as the condition was identified through hospital records for hospitalization for childbirth, leading to a non-differential bias of the estimates towards the null. Similarly, we probably underestimated tobacco use, as it was only assessed by the delivery of nicotine replacement therapy before or during pregnancy. Moreover, we had no data on alcohol consumption, family history of hypertension, and weight gain during pregnancy.

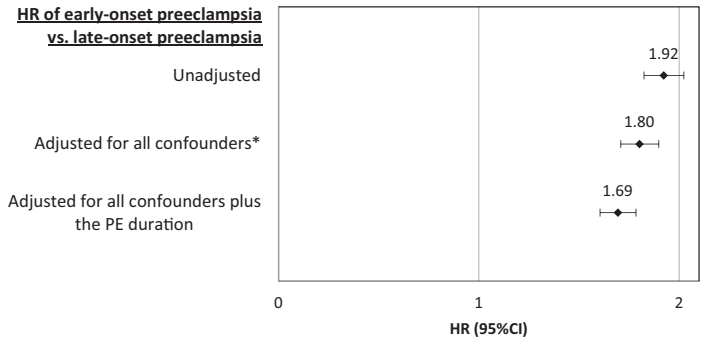


Figure 4 Hazard ratios of chronic hypertension in early-onset pre-eclampsia vs. late-onset pre-eclampsia. CI, confidence interval; HR, hazard ratio. *Confounders: year of delivery, maternal age, social deprivation, gestational diabetes, obesity, tobacco, and history of diabetes.

Finally, since our study focused on primiparous women, our results cannot be extrapolated to all pregnancies. Further studies should be conducted to study the impact of repeated HDP on chronic hypertension.

Conclusion

Hypertensive disorders of pregnancy in primiparous women were associated with a substantially increased risk of developing chronic hypertension in the first years following delivery. Active screening strategies for hypertension should be implemented for women with HDP, especially those with early or severe PE, or PE following GH. Further research is needed to better understand the reasons underlying the early onset of chronic hypertension following delivery, and guidelines should be developed to improve hypertension screening and management as well as cardiovascular prevention for these women.

Supplementary material

Supplementary material is available at *European Heart Journal* online.

Declaration of Helsinki and ethics approval

The authors state that this study complies with the Declaration of Helsinki. In line with French national regulations and ethics committee, participant consent was not required for this study. *Santé Publique France*—the French public health agency—has full and chronic access to the SNDS (governmental deliberation no. 2016-316, 13 October 2016).

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Data availability

We cannot share National Health Data System data as they are only available on a secure portal. Authorisation to access this portal needs registration and clearance.

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