ORIGINAL ARTICLE

Delivery Blood Pressure and Other First Pregnancy Risk Factors in Relation to Hypertensive Disorders in Second Pregnancies

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BACKGROUND
First pregnancy characteristics and blood pressure (BP) measures may be associated with second pregnancy hypertensive disorder risk. We examined the association between first pregnancy risk factors and second pregnancy hypertensive disorders.

METHODS
Electronic medical records of nulliparas (n = 26,787) delivering at least twice in Utah (2002–2010) were used. Polychotomous logistic regression models estimated the association of first pregnancy risk factors with second pregnancy hypertensive disorders (gestational hypertension, preeclampsia, or chronic hypertension) stratified by first pregnancy hypertensive status and adjusted for second characteristics.

RESULTS
Among normotensive women in their first pregnancy, preterm birth (<34 weeks) and elevated BP at delivery admission in the first pregnancy increased odds of all incident hypertensive disorders in the second. Even borderline admission BP (either systolic or diastolic BP: 130–139 or 85–89 mm Hg, respectively) was associated with a doubling of hypertensive disorder risk in a subsequent pregnancy. First pregnancy BP was also associated with recurrence risks for hypertensive disorders, but the relation was stronger for women with gestational hypertension in their first pregnancy with more than 2-fold elevated risk across all BP categories (odds ratios range: 2.32–12.6). However, the majority of women (75%) with a hypertensive disorder in the first pregnancy do not repeat this outcome in the second pregnancy.

CONCLUSION
Delivery admission BP of a first pregnancy was strongly related to hypertensive disorder incidence and recurrence in the subsequent pregnancy. Although crude, these measures may prove useful as a predictor of long-term maternal health and future pregnancy risk.

Keywords: blood pressure; chronic hypertension; hypertension; gestational hypertension; preeclampsia.

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Hypertensive disorders during pregnancy complicate up to 8% of pregnancies in the United States and remain a major cause of neonatal and maternal morbidity and mortality.[1] Recent evidence suggests that elevated blood pressure (BP) during pregnancy, irrespective of the type and even in the absence of known risk factors such as overweight/obesity, advanced maternal age, and smoking, is indicative of long-term maternal risk of cardiovascular disease, chronic kidney disease, and diabetes mellitus.[2] Risk factors for hypertensive disorders of pregnancy are fairly well described,[3,4] particularly for preeclampsia[5–7] but relatively little attention has been given to the potential contribution of first pregnancy BP and other first pregnancy characteristics to the risk of hypertensive disorders in a second pregnancy. Such information might prove useful in counseling women postpartum on their future risk of hypertensive disorders in subsequent pregnancies. The older literature noted that postpartum renal biopsies were once utilized to predict hypertensive disorders in a subsequent pregnancy. However, this approach was abandoned due to insufficient reliability combined with the risks of the procedure.[8,9]

Using data from the National Institute of Child Health and Human Development (NICHD) Consecutive Pregnancy Study, which includes women with at least 2 consecutive deliveries, we assessed the impact of first pregnancy characteristics and BP measures on the odds of developing a hypertensive disease in a subsequent pregnancy.

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METHODS

Study population

The NICHD Consecutive Pregnancy Study is a longitudinal retrospective cohort study of 51,086 women who delivered at least twice and up to 6 times at 20 hospitals in the state of Utah from 2002 to 2010. Data were extracted from maternal and infant (livebirths or stillbirths at ≥20 weeks' gestation) electronic medical records and were supplemented with International Classification of Diseases, 9th revision (ICD-9) discharge codes. Study sites obtained approval from their individual institutional review boards.

We restricted our data to nulliparous women at study entry with singleton deliveries in their first 2 pregnancies during the study period. We excluded women with inconsistent information on hypertensive status such as women with induced labor due to hypertension or on hypertensive medications with no hypertensive diagnosis recorded (n = 114). As we were interested in the factors that increased the odds of transitioning from one state of BP (normotensive or hypertensive status) to another, we excluded women with a history of chronic hypertension (n = 176) prior to the first pregnancy resulting in a total sample size of 26,787 nulliparous women with 53,574 singleton deliveries. Women who developed chronic hypertension by their second pregnancy were not excluded. Due to small numbers, women who developed eclampsia (n = 20) were combined with preeclampsia, and women who developed superimposed preeclampsia (n = 48) were combined with chronic hypertension.

Hypertensive disorders

The main outcomes for this analysis were hypertensive disorders during the second pregnancy which included gestational hypertension, preeclampsia/eclampsia, and chronic hypertension. Hypertensive disorders were clinical definitions as recorded in the patient medical record. During the study period, the definitions widely adopted in US clinical practice were as follows: preeclampsia and gestational hypertension were defined as having a systolic BP (SBP) ≥140 mm Hg, a diastolic BP (DBP) ≥90 mm Hg occurring after 20 weeks' gestation among previously normotensive women with and without proteinuria and urinary excretion ≥0.3 g protein in 24-hour urine specimen, respectively;[10] eclampsia was defined as preeclampsia with new-onset seizures;[11] chronic hypertension was defined as hypertension ≥140 mm Hg SBP or ≥90 mm Hg DBP occurring before pregnancy or prior to 20 weeks' gestation.[12] Maternal hypertensive status was ascertained from electronic medical records supplemented with ICD-9 codes from the discharge summary. Women with a diagnosis in either data source were coded as having the condition. ICD-9 codes used to identify hypertensive disorders and other maternal complications are listed in Supplemental Table S1.

Predictors

First pregnancy predictors included: small for gestational age birth (<5th percentile of sex-specific birth weight for gestational age),[13] early preterm birth (<34 weeks' gestation), and delivery admission SBP/DBP categorized into 3 groups: normotensive if both SBP and DBP were ≤129/84 mm Hg, borderline if either SBP or DBP was 130–139/85–89 mm Hg, and hypertensive if either SBP or DBP was ≥140/90 mm Hg.[14] When examining women with gestational hypertension or preeclampsia in their first pregnancy, the hypertensive group was further divided into hypertensive stage 1 if either SBP or DBP was 140–159/90–99 mm Hg and hypertensive stage 2/3 if either SBP or DBP was ≥160/100 mm Hg.

Covariates

Second pregnancy covariates included: maternal race/ethnicity (non-Hispanic White, other), marital status (married, not married), maternal age (<29, 30–34, ≥35 years), insurance type (public, private), prepregnancy body mass index (underweight and normal (<24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), class I obese (30.0–34.9 kg/m^2), class II and III obese (≥35.0 kg/m^2)), interpregnancy interval defined as the time elapsed between the woman's first delivery date and the date of the last menstrual period of her second pregnancy (0–5, 6–11, 12–17, 18–23, ≥24 months), maternal smoking during pregnancy (yes, no), alcohol use during pregnancy (yes, no), and the difference in prepregnancy weight between the first 2 births (lost >4.5 kg, maintained within 4.5 kg, and gained >4.5 kg).[15]

Statistical analysis

Stratifying by hypertensive status in the first pregnancy (i.e., normotensive women, women with gestational hypertension, and women with preeclampsia), we fit 3 polychotomous logistic regression models examining the association between first pregnancy admission BP and other first pregnancy factors and the development of gestational hypertension, preeclampsia, or chronic hypertension in the second pregnancy. Polychotomous logistic regression is an extension of the logistic regression from a binary outcome to an outcome that has more than 2 nominal categories.[16] Specifically, the association between first pregnancy variables and second pregnancy gestational hypertension, preeclampsia, or chronic hypertension is assessed by estimating the odds ratios (ORs) relative to being normotensive in the second pregnancy (reference category). We report the ORs and the 95% confidence intervals (CIs) from the polychotomous logistic models adjusting for second pregnancy characteristics. As the main focus of our paper was examining first pregnancy factors in association with second pregnancy hypertensive disorders, we did not focus on demographics or other risk factors such as smoking, but only provided these findings in the Supplemental Table S2. All analyses were conducted using SAS (version 9.3; SAS Institute, Cary, NC). A P value <0.05 was considered for statistical significance.

RESULTS

Women who were normotensive in their first pregnancy were nearly all normotensive in their second pregnancy (97%), while 1.2% developed gestational hypertension and 1.1% developed preeclampsia (Table 1). Over 75% of

Table 1. Recurrent hypertensive disorder type in 2nd pregnancy by hypertensive disorder type in 1st pregnancy

Nulliparous women at study entry	2nd pregnancy, *N* (%)						
1st pregnancy	Normotensive (*n* = 25,475)	Gestational hypertension (*n* = 642)	Preeclampsia (*n* = 493)	Eclampsia[a] (*n* = 3)	Chronic hypertension[b] (*n* = 281)	Superimposed preeclampsia[b] (*n* = 69)	Incidence/ recurrence[c]
Normotensive (*n* = 23,913)	23,301 (97.4)	284 (1.2)	253 (1.1)	2 (0.01)	57 (0.24)	16 (0.07)	612 (2.6)
Gestational hypertension (*n* = 1,538)	1,195 (77.7)	200 (13.0)	86 (5.6)	–	44 (2.9)	13 (0.85)	343 (22.3)
Preeclampsia (*n* = 1,319)	968 (73.4)	156 (11.8)	150 (11.4)	1 (0.08)	25 (1.9)	19 (1.4)	351 (26.6)
Eclampsia (*n* = 17)[a]	11 (64.7)	2 (11.8)	4 (23.5)	–	–	–	
Chronic hypertension (*n* = 114)[d]	–	–	–	–	103 (90.4)	11 (9.7)	–
Superimposed preeclampsia (*n* = 62)[d]	–	–	–	–	52 (83.9)	10 (16.1)	–

[a]Women who developed eclampsia (*n* = 17 in the 1st pregnancy, *n* = 3 in the 2nd pregnancy) were combined with the preeclampsia group in the 1st pregnancy or in the 2nd pregnancy.

[b]Women who developed chronic hypertension (*n* = 126) or superimposed preeclampsia (*n* = 48) by the time of their 2nd pregnancy were combined.

[c]Incidence/recurrence of hypertensive disorder in the 2nd pregnancy by hypertensive disorder status in the 1st pregnancy.

[d]Women with a history of chronic hypertension/superimposed preeclampsia in the 1st pregnancy (*n* = 176) were excluded from further analyses.

women with gestational hypertension or eclampsia/preeclampsia in their first pregnancy were normotensive in the second. Women with eclampsia/preeclampsia in their first pregnancy were equally likely to develop either gestational hypertension (11.8%) or eclampsia/preeclampsia (11.6%) in their second pregnancy. Women with gestational hypertension in their first pregnancy were more likely to have gestational hypertension recurrence (13%) in their second pregnancy rather than develop preeclampsia (5.6%). Among women with either gestational hypertension or preeclampsia in the first pregnancy, more than 3% developed chronic hypertension/superimposed preeclampsia in their second pregnancy (3.7% and 3.3%, respectively).

Table 2 displays second pregnancy maternal characteristics and first pregnancy obstetric outcomes among women who were normotensive in their first pregnancy and either remained normotensive in their second pregnancy or developed gestational hypertension, preeclampsia, or chronic hypertension. Women with preexisting diabetes mellitus, major postpartum weight retention/weight gain, or higher second prepregnancy body mass index were more likely to develop a hypertensive disorder in their second pregnancy. Women with a preterm birth <34 weeks and with higher admission BP in the first pregnancy were also more likely to develop a hypertensive disorder in the second pregnancy.

The odds of developing gestational hypertension, preeclampsia, or chronic hypertension in the second pregnancy in association with first pregnancy factors adjusting for second pregnancy covariates are reported in Table 3. Among women who were normotensive in their first pregnancy, early preterm delivery in the first pregnancy and elevated BP at time of hospital admission for the first delivery were consistently associated with increased risk of developing all of the hypertensive disorders in the second pregnancy. Increased BP category showed a dose–response relationship with subsequent hypertensive disorder risk. Women whose first pregnancy SBP/DBP was 130–139/85–89 mm Hg were 2 times while those whose first pregnancy SBP/DBP was ≥140/90 mm Hg were 3–4 times more likely to develop a hypertensive disorder in their second pregnancy across clinical type. Small for gestational age birth in the first pregnancy was an additional risk factor for subsequent preeclampsia only (OR = 1.73; 95% CI: 1.05–2.84). Supplementary Table S2 shows measures of associations with all second pregnancy covariates.

With regards to recurrent hypertensive disorder, a strong dose–response relationship remained between admission BP and risk for women with gestational hypertension in their first pregnancy (Table 3). Women who had preeclampsia in their first pregnancy had increased risk for gestational hypertension or preeclampsia in the second when admission BP for the first pregnancy was high with no strong dose–response relationship observed. Among women with gestational hypertension in their first pregnancy, early preterm in the first pregnancy was associated with chronic hypertension in the second (OR = 4.85; 95% CI: 1.05–22.4), while among those who had preeclampsia in their first pregnancy, first pregnancy preterm status increased the odds of preeclampsia recurrence (OR = 1.78; 95% CI: 1.03–3.11).

Table 2. 2nd pregnancy maternal characteristics and 1st pregnancy obstetric outcomes among 1st pregnancy normotensive women

Maternal characteristics of the 2nd pregnancy/obstetric outcomes of the 1st pregnancy	2nd pregnancy outcome			
	Normotensive (*N* = 23,291)	Gestational hypertension (*N* = 284)	Preeclampsia (*N* = 255)	Chronic hypertension (*N* = 73)
Maternal characteristics of the 2nd pregnancy				
Maternal age (years)[a,b]	26.1 (4.1)	26.5 (4.3)	26.5 (4.3)	27.7 (4.6)
Age >35 years	678 (2.9)	12 (4.2)	5 (2.0)	4 (5.5)
Non-Hispanic White	20,247 (87.0)	261 (91.9)	223 (87.8)	63 (86.3)
Private insurance	16,895 (72.5)	213 (75.0)	167 (65.5)	48 (65.8)
Married	20,743 (89.1)	259 (91.2)	220 (86.3)	62 (84.9)
Smoke during pregnancy	671 (2.9)	12 (4.2)	10 (3.9)	7 (9.6)
Alcohol during pregnancy	378 (1.6)	4 (1.4)	7 (2.8)	0 (0)
Interpregnancy interval (days)[a]	579.8 (335.2)	638.0 (370.4)	646.9 (404.1)	719.4 (474.5)
Interpregnancy interval, (months)				
0–5	1,337 (5.7)	16 (5.6)	20 (7.8)	3 (4.1)
6–11	4,298 (18.5)	50 (17.6)	33 (12.9)	17 (23.3)
12–17	6,177 (26.5)	49 (17.3)	71 (27.8)	16 (21.9)
18–23	5,108 (21.9)	68 (23.9)	39 (15.3)	6 (8.2)
≥24	6,371 (27.4)	101 (35.6)	92 (36.1)	31 (42.5)
Preexisting diabetes mellitus	313 (1.3)	4 (1.4)	4 (1.6)	8 (11.0)
Asthma/depression/thyroid disease	4,758 (20.4)	68 (23.9)	53 (20.8)	25 (34.3)
Major postpartum weight retention/weight gain ≥4.55 kg	5,553 (24.6)	118 (43.5)	90 (36.1)	33 (48.5)
Prepregnancy BMI, (kg/m^2)[a]	24.3 (5.2)	28.0 (7.0)	27.2 (6.5)	32.9 (8.5)
Prepregnancy BMI, (kg/m^2)				
Underweight and Normal (≤24.9)	15,136 (65.9)	109 (39.1)	117 (46.1)	16 (22.9)
Obese class I (25.0–29.9)	4,867 (21.2)	88 (31.5)	68 (26.8)	11 (15.7)
Obese class II (30.0–34.9)	1,873 (8.2)	37 (13.3)	34 (13.4)	14 (20.0)
Obese class II and III (≥35.0)	1,086 (4.7)	45 (16.1)	35 (13.8)	29 (41.4)
Obstetric outcomes of the 1st pregnancy				
SGA in 1st pregnancy	933 (4.0)	16 (5.7)	18 (7.1)	3 (4.1)
Preterm <34 weeks in 1st pregnancy[c]	366 (1.6)	14 (4.9)	15 (5.9)	4 (5.5)
Spontaneous preterm	299 (81.7)	10 (71.4)	14 (93.3)	4 (100)
Indicated preterm	40 (10.9)	3 (21.4)	1 (6.7)	0
1st pregnancy admission blood pressure[d]				
Normotensive	13,325 (57.3)	85 (30.0)	78 (30.6)	20 (27.8)
Borderline	5,945 (25.5)	89 (31.5)	77 (30.2)	22 (30.6)
Hypertensive	4,007 (17.2)	109 (38.5)	100 (39.2)	30 (41.7)
Gestational diabetes in 1st pregnancy	407 (1.8)	10 (3.5)	5 (2.0)	3 (4.1)

Data were missing for: race/ethnicity: 27; married: 2; smoke: 18; alcohol: 61; major postpartum weight retention/weight gain: 702; prepregnancy BMI: 338; SGA in 1st pregnancy: 25; 1st pregnancy admission blood pressure: 16. All figures are *N* (%) unless otherwise stated.

Abbreviations: BMI: body mass index; SGA: small for gestational age.

[a]Mean (SD).

[b]At the 1st delivery, the mean (SD) of age of the overall group was 23.8 (4.0) years, range: 13–43 years.

[c]28 had elective preterm delivery.

[d]1st pregnancy admission blood pressure categorized as: normotensive if both systolic blood pressure (SBP) and diastolic blood pressure (DBP) were ≤129/84 mm Hg, borderline if either SBP or DBP was 130–139/85–89 mm Hg, and hypertensive if either SBP or DBP was ≥140/90 mm Hg.

Table 3. Polychotomous regression modeling gestational hypertension, preeclampsia, and chronic hypertension risk in the 2nd pregnancy

	2nd pregnancy outcome					
	Gestational hypertension		Preeclampsia		Chronic hypertension	
	OR	95% CI	OR	95% CI	OR	95% CI
Normotensive in the 1st pregnancy, *N* = 23,064						
1st pregnancy SGA status						
No	1.00	Referent	1.00	Referent	1.00	Referent
Yes	1.43	0.84–2.44	**1.73**	**1.05–2.84**	1.03	0.32–3.38
1st pregnancy preterm <34 weeks status						
No	1.00	Referent	1.00	Referent	1.00	Referent
Yes	**3.18**	**1.64–6.15**	**4.69**	**2.69–8.20**	**3.96**	**1.19–13.2**
1st pregnancy admission blood pressure[a]						
Normotensive	1.00	Referent	1.00	Referent	1.00	Referent
Borderline	**2.07**	**1.52–2.81**	**2.02**	**1.46–2.78**	**2.04**	**1.07–3.89**
Hypertensive	**3.42**	**2.54–4.61**	**3.81**	**2.80–5.19**	**3.76**	**2.06–6.86**
Gestational diabetes in 1st pregnancy						
No	1.00	Referent	1.00	Referent	1.00	Referent
Yes	1.77	0.91–3.43	0.98	0.40–2.44	1.02	0.29–3.55
Gestational hypertension in the 1st pregnancy, *N* = 1,498						
1st pregnancy SGA status						
No	1.00	Referent	1.00	Referent	1.00	Referent
Yes	0.98	0.47–2.06	0.21	0.03–1.57	0.72	0.16–3.14
1st pregnancy preterm <34 weeks status						
No	1.00	Referent	1.00	Referent	1.00	Referent
Yes	1.35	0.27–3.68	–	–	**4.85**	**1.05–22.4**
1st pregnancy admission blood pressure[a]						
Normotensive	1.00	Referent	1.00	Referent	1.00	Referent
Borderline	**2.32**	**1.26–4.29**	**8.52**	**1.97–36.9**	2.71	0.75–9.83
Hypertensive stage 1	**2.75**	**1.55–4.88**	**9.14**	**2.18–38.4**	**3.47**	**1.02–11.8**
Hypertensive stage 2/3	**3.85**	**2.00–7.39**	**12.6**	**2.81–56.8**	**5.94**	**1.61–21.9**
Gestational diabetes in 1st pregnancy						
No	1.00	Referent	1.00	Referent	1.00	Referent
Yes	0.82	0.31–2.19	1.69	0.55–5.21	1.26	0.31–5.05
Preeclampsia in the 1st pregnancy, *N* = 1,288						
1st pregnancy SGA status						
No	1.00	Referent	1.00	Referent	1.00	Referent
Yes	1.03	0.53–1.98	0.58	0.27–1.27	0.52	0.11–2.45
1st pregnancy preterm <34 weeks status						
No	1.00	Referent	1.00	Referent	1.00	Referent
Yes	1.00	0.52–1.93	**1.78**	**1.03–3.11**	1.41	0.47–4.25

Table 3. Continued

	2nd pregnancy outcome					
	Gestational hypertension		Preeclampsia		Chronic hypertension	
	OR	95% CI	OR	95% CI	OR	95% CI
1st pregnancy admission blood pressure[a]						
Normotensive	1.00	Referent	1.00	Referent	1.00	Referent
Borderline	1.95	0.85–4.51	0.99	0.45–2.20	0.59	0.16–2.20
Hypertensive stage 1	**2.85**	**1.32–6.18**	1.66	0.84–3.30	1.38	0.48–3.94
Hypertensive stage 2/3	**3.69**	**1.65–8.25**	**2.96**	**1.46–6.01**	0.88	0.25–3.05
Gestational diabetes in 1st pregnancy						
No	1.00	Referent	1.00	Referent	1.00	Referent
Yes	0.85	0.28–2.58	1.52	0.63–3.68	0.57	0.11–2.89

Adjusted for maternal age, race/ethnicity, insurance, marital status, smoking during pregnancy, alcohol during pregnancy, interpregnancy interval, preexisting diabetes mellitus, asthma/depression/thyroid disease, 1st and 2nd prepregnancy weight difference, and prepregnancy body mass index.

Bold values indicate a significance of $p < 0.05$.

Abbreviation: CI, confidence interval; OR, odds ratio; SGA: small for gestational age.

[a]1st pregnancy admission blood pressure categorized as: normotensive if both systolic blood pressure (SBP) and diastolic blood pressure (DBP) were ≤129/84 mm Hg, borderline if either SBP or DBP was 130–139/85–89 mm Hg, hypertensive stage 1 if either SBP or DBP was 140–159/90–99 mm Hg, hypertensive stage 2/3 if either SBP or DBP was ≥160/100 mm Hg. Among women who were normotensive in their 1st pregnancy, hypertensive stages were combined into one group with either SBP or DBP being ≥140/90 mm Hg.

DISCUSSION

This longitudinal retrospective study of over 23,000 nulliparous women with 2 consecutive singleton pregnancies shows that among normotensive women, first pregnancy elevated admission BP and preterm delivery <34 weeks were associated with increased odds for all types of second pregnancy hypertensive disorders. Among women who had gestational hypertension in their first pregnancy, admission BP also remained a good indicator for second pregnancy risk for those who do end up having a hypertensive disorder diagnosis.

Previously, studies have examined the significance of prepregnancy and early pregnancy BP measures in predicting hypertensive disorders during pregnancy.[6,7,17–19] While elevated SBP and DBP measures prior to 22 weeks' gestation have been associated with increased risk of newly developed hypertension,[7] more recent studies found that this risk even exists with prepregnancy BP measures.[17] We expand on this literature finding that independent of second prepregnancy body mass index and other factors, elevated pregnancy admission BP in women who were normotensive in their first pregnancy increased the risk of developing hypertensive disorders in the second pregnancy with no preference for any clinical type. We also used BP measurements taken at admission to the hospital for labor and delivery, a period marked by additional stress, which could have been an indicator of more reactive BP rather than regular/homeostatic BP. Evidence shows that reactive BP is predictive of future cardiovascular events.[20] However, similar to another previous study,[21] we found that admission BP was likely valid as women diagnosed with a hypertensive disorder during or before pregnancy had higher admission BP levels than women who were normotensive (data not shown). We also observed that the risks increased in a dose–response manner suggesting that the single admission BP measurement, while having little prediction value for the intensity of repeat hypertension, might still be useful for monitoring patients more closely.

Approximately 25% of women in our study experienced recurrence of a hypertensive disorder. Recurrence rates of preeclampsia (11.6%) and gestational hypertension (13.0%) in our study were lower than previously reported in the literature (approximately 14% and 25%, respectively).[22,23] The discrepant rates may reflect population differences.

Whether gestational hypertension and preeclampsia represent 2 distinct diseases with different underlying causes or just different severities of the same disease process is unclear.[3,4,24] While the dose–response relationship between first pregnancy admission BP and any second pregnancy hypertensive disorder was observed among women with gestational hypertension in their first pregnancy, the same relationship was less robust among women with preeclampsia in their first pregnancy. As such, first pregnancy admission BP may still serve as an indicator among those with a hypertension diagnosis in their first pregnancy.

Having a preterm birth prior to 34 weeks in a normotensive first pregnancy increased the risk of any type of hypertensive disorder in the second pregnancy. This increased risk remained even after restricting delivery prior to 34 weeks to spontaneous preterm birth (data not shown). These findings are consistent with prior work from our group demonstrating that history of spontaneous preterm birth is associated with increased risk of indicated preterm delivery in a subsequent pregnancy.[25] This might be due to a common pathway shared by these conditions or it might be that some of these women would have been diagnosed with a hypertensive

disorder later in pregnancy but they delivered prior to the clinical manifestation of the disorder.[23]

Limitations of the current study include lack of data on dates of diagnosis of conditions. It may be that associations differ based on the severity and the timing of preeclampsia diagnosis. Early onset hypertension diagnosed at ≤34 weeks of gestation in women with gestational hypertension or preeclampsia in the first pregnancy has been shown to increase the risk of chronic hypertension by the second pregnancy.[26] Restricting our analyses to presumably "late onset" preeclampsia in the first pregnancy (preeclampsia and delivery at ≥37 weeks) yielded similar results. We lacked data on family history of hypertensive disorders and paternity and were unable to assess the impact of changing paternity on subsequent preeclampsia risk. However, we expect that the majority of women in our study population are in stable relationships as married women comprised 83%–89% of our sample for both pregnancies in comparison to the 41.5% national estimate.[27] As our study population was mainly comprised of Caucasians, our findings may also not be generalizable to non-Caucasian populations. Caution should be used in interpreting the weak associations of the ORs in the range between 1 and 2 particularly those related to 1st pregnancy small for gestational age and preterm status and the increased risk of preeclampsia.[28] Finally, while there may have been potential misclassification of hypertensive disorders, our diagnoses of gestational hypertension, preeclampsia, and chronic hypertension were as recorded in the medical record. As such, our findings are applicable to a clinical setting. It is also reassuring that our rates of gestational hypertension and preeclampsia were similar to what has been reported in the literature. Rates of preeclampsia in the Swedish Medical Birth Register were 4.1% in the first pregnancy and 1.7% in the second pregnancy similar to our findings of 4.9% and 1.8%, respectively.[29]

SUPPLEMENTARY MATERIAL

Supplementary materials are available at *American Journal of Hypertension* (http://ajh.oxfordjournals.org).

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DISCLOSURE

The authors declared no conflict of interest.

REFERENCES

1. Roberts JM, Pearson G, Cutler J, Lindheimer M. Summary of the NHLBI Working Group on Research on Hypertension During Pregnancy. *Hypertension* 2003; 41:437–445.
2. Männistö T, Mendola P, Vääräsmäki M, Järvelin MR, Hartikainen AL, Pouta A, Suvanto E. Elevated blood pressure in pregnancy and subsequent chronic disease risk. *Circulation* 2013; 127:681–690.
3. Ros HS, Cnattingius S, Lipworth L. Comparison of risk factors for preeclampsia and gestational hypertension in a population-based cohort study. *Am J Epidemiol* 1998; 147:1062–1070.
4. Villar J, Carroli G, Wojdyla D, Abalos E, Giordano D, Ba'aqeel H, Farnot U, Bergsjø P, Bakketeig L, Lumbiganon P, Campodónico L, Al-Mazrou Y, Lindheimer M, Kramer M; World Health Organization Antenatal Care Trial Research Group. Preeclampsia, gestational hypertension and intrauterine growth restriction, related or independent conditions? *Am J Obstet Gynecol* 2006; 194:921–931.
5. Duckitt K, Harrington D. Risk factors for pre-eclampsia at antenatal booking: systematic review of controlled studies. *BMJ* 2005; 330:565.
6. Sibai BM, Gordon T, Thom E, Caritis SN, Klebanoff M, McNellis D, Paul RH. Risk factors for preeclampsia in healthy nulliparous women: a prospective multicenter study. The National Institute of Child Health and Human Development Network of Maternal-Fetal Medicine Units. *Am J Obstet Gynecol* 1995; 172:642–648.
7. Sibai BM, Ewell M, Levine RJ, Klebanoff MA, Esterlitz J, Catalano PM, Goldenberg RL, Joffe G. Risk factors associated with preeclampsia in healthy nulliparous women. The Calcium for Preeclampsia Prevention (CPEP) Study Group. *Am J Obstet Gynecol* 1997; 177:1003–1010.
8. Kuller JA, D'Andrea NM, McMahon MJ. Renal biopsy and pregnancy. *Am J Obstet Gynecol* 2001; 184:1093–1096.
9. Lindheimer MD, Spargo BH, Katz AI. Renal biopsy in pregnancy-induced hypertension. *J Reprod Med* 1975; 15:189–194.
10. American College of Obstetricians and Gynecologists. Hypertension in pregnancy. Report of the American College of Obstetricians and Gynecologists' Task Force on Hypertension in Pregnancy. *Obstet Gynecol* 2013; 122:1122–1131.
11. ACOG Committee on Practice Bulletins–Obstetrics. ACOG practice bulletin. Diagnosis and management of preeclampsia and eclampsia. Number 33, January 2002. *Obstet Gynecol* 2002; 99:159–167.
12. Seely EW, Ecker J. Chronic hypertension in pregnancy. *Circulation* 2014; 129:1254–1261.
13. Kramer MS, Platt RW, Wen SW, Joseph KS, Allen A, Abrahamowicz M, Blondel B, Bréart G; Fetal/Infant Health Study Group of the Canadian Perinatal Surveillance System. A new and improved population-based Canadian reference for birth weight for gestational age. *Pediatrics* 2001; 108:E35.
14. US Department of Health and Human Services. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. 2004.
15. Olson CM, Strawderman MS, Hinton PS, Pearson TA. Gestational weight gain and postpartum behaviors associated with weight change from early pregnancy to 1 y postpartum. *Int J Obes Relat Metab Disord* 2003; 27:117–127.
16. Agresti A. *Categorical Data Analysis*. Wiley: New York, 1990.
17. Magnussen EB, Vatten LJ, Lund-Nilsen TI, Salvesen KA, Davey Smith G, Romundstad PR. Prepregnancy cardiovascular risk factors as predictors of pre-eclampsia: population based cohort study. *BMJ* 2007; 335:978.
18. Odegård RA, Vatten LJ, Nilsen ST, Salvesen KA, Austgulen R. Risk factors and clinical manifestations of pre-eclampsia. *BJOG* 2000; 107:1410–1416.
19. Zhang J, Troendle JF, Levine RJ. Risks of hypertensive disorders in the second pregnancy. *Paediatr Perinat Epidemiol* 2001; 15:226–231.
20. Gustavsen PH, Høegholm A, Bang LE, Kristensen KS. White coat hypertension is a cardiovascular risk factor: a 10-year follow-up study. *J Hum Hypertens* 2003; 17:811–817.
21. Wells EM, Navas-Acien A, Herbstman JB, Apelberg BJ, Silbergeld EK, Caldwell KL, Jones RL, Halden RU, Witter FR, Goldman LR. Low-level lead exposure and elevations in blood pressure during pregnancy. *Environ Health Perspect* 2011; 119:664–669.
22. Brown MA, Mackenzie C, Dunsmuir W, Roberts L, Ikin K, Matthews J, Mangos G, Davis G. Can we predict recurrence of pre-eclampsia or gestational hypertension? *BJOG* 2007; 114:984–993.
23. Mostello D, Kallogjeri D, Tungsiripat R, Leet T. Recurrence of preeclampsia: effects of gestational age at delivery of the first pregnancy, body mass index, paternity, and interval between births. *Am J Obstet Gynecol* 2008; 199:55.e1–55.e7.
24. Seely EW, Solomon CG. Insulin resistance and its potential role in pregnancy-induced hypertension. *J Clin Endocrinol Metab* 2003; 88:2393–2398.
25. Laughon SK, Albert PS, Leishear K, Mendola P. The NICHD Consecutive Pregnancies Study: recurrent preterm delivery by subtype. *Am J Obstet Gynecol* 2014; 210:131.e1–131.e8.

26. Hjartardottir S, Leifsson BG, Geirsson RT, Steinthorsdottir V. Recurrence of hypertensive disorder in second pregnancy. *Am J Obstet Gynecol* 2006; 194:916–920.
27. US Department of Health and Human Services. First marriages in the United States: Data from the 2006–2010 National Survey of Family Growth. 2012.
28. Grimes DA, Schulz KF. False alarms and pseudo-epidemics: the limitations of observational epidemiology. *Obstet Gynecol* 2012; 120:920–927.
29. Hernández-Díaz S, Toh S, Cnattingius S. Risk of pre-eclampsia in first and subsequent pregnancies: prospective cohort study. *BMJ* 2009; 338:b2255.