Hypertension

ORIGINAL ARTICLE

Blood Pressure 15 to 90 Days After a Hypertensive Disorder of Pregnancy and Later Hypertension

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BACKGROUND: Timely diagnosis of hypertension provides an opportunity for cardiovascular disease prevention after a hypertensive disorder of pregnancy. We assessed the association between blood pressure 15 to 90 days postpartum and incident hypertension after a hypertensive disorder of pregnancy.

METHODS: This was a retrospective cohort study of women with no preexisting hypertension and a hypertensive disorder of pregnancy between January 2014 and December 2017 at 2 health systems in the southeastern United States. Cox proportional hazards models assessed the association of postpartum blood pressure and incident hypertension over a median follow-up period of 9.9 months. Covariates selected via directed acyclic graph construction included type of hypertensive disorder, race, ethnicity, maternal age, smoking, body mass index, and gestational diabetes.

RESULTS: Out of 5657 women, only 2520 (45%) met the inclusion criteria; 39% (1584) of otherwise eligible individuals did not have a blood pressure check at 15 to 90 days postpartum. The hazards of incident hypertension during follow-up were significantly higher for those with higher systolic postpartum blood pressure (1.81 [95% CI, 1.46–2.24]). The estimated cumulative incidence of hypertension over the first 12 months of follow-up among participants with a blood pressure of 110/65 mm Hg was 4.5% (95% CI, 2.8%–6.1%), and with blood pressure 140/90, it was 12.0% (95% CI, 8.4%–17.2%).

CONCLUSIONS: The risk of incident hypertension after a hypertensive disorder of pregnancy is high in the first year postpartum especially for those with elevated systolic blood pressure postpartum. Despite this, for many participants, blood pressure was not measured within 15 to 90 days postpartum. ***(Hypertension.* 2026;83:272–281. DOI: 10.1161/HYPERTENSIONAHA.124.24393.)** • **Supplement Material**.

Key Words: hypertension ■ hypertension pregnancy induced ■ incidence ■ postpartum period

See Jensen et al

Cardiovascular disease (CVD) is the leading cause of death in women, and, though often preventable, CVD mortality among young women has disproportionately increased in recent years.[1] Hypertensive disorders of pregnancy (HDP), including gestational hypertension without proteinuria, preeclampsia without severe features, chronic hypertension with superimposed preeclampsia, and severe preeclampsia/eclampsia, are risk factors for CVD.[2] Administrative data from South Carolina births (2004–2016) show that HDPs confer additional risk of CVD events (eg, myocardial infarction, heart failure, stroke) within 5 years of delivery.[3]

The diagnosis and timely postpartum management of HDP provides an opportunity to improve the outcomes of future pregnancies and prevent long-term CVD morbidity and mortality. Pregnancy functions as a metabolic stress

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NOVELTY AND RELEVANCE

What Is New?

Regardless of blood pressure measure in the early postpartum period, there is a significant incidence of incident hypertension for patients who have experienced hypertension during pregnancy. The risk is higher with higher measurements in the early postpartum period.

What Is Relevant?

Significant proportions of patients who had a hypertensive disorder of pregnancy did not have follow-up blood pressure measured at the recommended time points in the early postpartum period.

Clinical/Pathophysiologic Implications?

Early identification of and management of hypertension can prevent morbidity and mortality in this population of young women who are art risk for heart disease.

Nonstandard Abbreviations and Acronyms

BP	blood pressure
CVD	cardiovascular disease
HDP	hypertensive disorder of pregnancy
HR	hazard ratio
ICD-CM 9/10	*International Classification of Diseases, Ninth/Tenth Revision, Clinical Modification*

test, identifying a predisposition to CVD before it leads to morbidity and mortality.[4] The diagnosis of HDPs could result in prevention opportunities for individuals who might otherwise not come to clinical attention early enough to prevent morbidity and mortality. Current guidelines for short- and long-term postpartum management of individuals with HDP are relatively recent and somewhat inconsistent.[5] However, all agree that management of CVD risk factors, such as hypertension, is important for individuals after an HDP. For decades, obstetric guidelines have recommended a comprehensive postpartum visit within 90 days postpartum to include blood pressure (BP) screening for all individuals who have given birth. As of 2013, the American College of Obstetricians and Gynecologists (ACOG) recommended that individuals with HDPs also have a BP evaluation 3 to 10 days after delivery, be educated on their individual risk, and have a repeat BP evaluation at their comprehensive visit at 15 to 90 days postpartum with the goal of creating a postpartum management plan for their hypertension.[6,7] The American Heart Association (AHA) recommends frequent cardiac risk factor screening assessments in the first year after an HDP at 6 weeks, 12 weeks, 6 months, and 12 months postpartum, with appropriate transition from postpartum to longitudinal primary care around the 8- to 12-week mark.[8] Though individuals with HDP may be more likely to attend postpartum visits than others, up to 40% do not access routine postpartum care.[9] In addition to completing postpartum care, individuals with HDPs should have a primary care visit within 6 months post-delivery.[8]

Early identification and appropriate management of hypertension is one key aspect in the prevention of CVD and adverse pregnancy outcomes.[5] Few studies investigate the risk of hypertension after an HDP in US populations.[4,10] Among those that do, few examine the risk of incident hypertension during the first year after delivery. This makes it difficult for obstetric and primary care providers to appropriately counsel postpartum patients with an HDP about their individual risk or to create a transition plan from obstetric to primary care.

To better understand the early risk of incident hypertension after an HDP event, the primary objective of this analysis was to estimate the associations between systolic and diastolic BPs during the early postpartum period and the relative hazard of incident hypertension during follow-up, particularly during the first postpartum year. We hypothesized that higher postpartum systolic and diastolic BPs measured at the time of the comprehensive postpartum visit 15 to 90 days postpartum would be associated with a higher incidence of incident hypertension diagnosis during subsequent primary care follow-up. A secondary objective was to understand the proportion of individuals who had BP measurements per ACOG guidelines.

METHODS

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Study Design

This was a planned secondary analysis of a retrospective cohort study investigating factors associated with postpartum risk of hypertension among people aged 13 to 54 years diagnosed with an HDP at 2 academic health systems. Reporting of Studies Conducted Using Observational Routinely Collected Health Data guidelines were followed (Table S1).

Source of Participants and Data

We used data from the Carolinas Collaborative, a partnership between the National Institutes of Health's Clinical and Translational Science Award hubs in North and South Carolina which harmonizes the electronic health data across institutions to expedite clinical research.[11] Using the common data model of the Carolinas Collaborative, we identified women with an HDP and delivering at 2 academic health systems in the southeastern United States between January 1, 2007 and December 31, 2017. Each health system includes a main campus as well as smaller, community hospitals. Women aged 13 to 54 years with an *International Classification of Diseases, Ninth/Tenth Revision, Clinical Modification* (ICD-CM 9/10) code for an HDP were included (ICD-10-CM O11, O13, O14, O15 and ICD-9 642.3, 642.4, 642.5, 642.6, 642.7). A team from each institution abstracted the data for eligible patients from their respective electronic health records. They then shared the data with each other to match patients who had records in both health systems using a hashing algorithm which contained the first 3 digits of the first name, first 8 digits of the last name, sex, and date of birth. The data were merged and de-identified except for dates of service, dates of birth, and zip codes.

For the purposes of this analysis, we included HDP-affected deliveries which occurred in 2014 or later and had a BP measured 15 to 90 days postpartum in either system by any provider. We excluded the population who gave birth before 2014 in this analysis due to a high proportion of missing data, especially BP measurements. The Epic, Epic Systems Corporation rolled out in both institutions in 2014 and likely contributed to higher data quality after that point. Also, these births occurred mostly before current postpartum care guidelines for individuals with HDPs. In women who had multiple recorded pregnancies complicated by an HDP, only the first pregnancy was included. We excluded records that had improbable gestational age at delivery (<0 or >43 weeks). Given our focus on incident hypertension related to postpartum BP measurement, for this analysis we excluded patients who had a diagnosis of preexisting hypertension before or during pregnancy or at the time of the first BP measurement during the 15 to 90 days postpartum window. Per national and international guidelines, the diagnosis of incident hypertension cannot be accurately made before 12 weeks of gestation due to transient changes in BP that occur during this period.[12–15]

Variables of Interest

The primary outcome was time to diagnosis of hypertension by any provider (ICD-10-CM I10 and I11; ICD-9 401 and 402) after the date of the 15 to 90 day BP check. Participants were censored at their last encounter available in the electronic health record or administratively censored at the end of the study on December 31, 2019. This means we may have had up to 6 years of follow-up, depending on the timing of delivery. We censored individuals at their last encounter to avoid including immortal person-time for participants whose outcomes we would never observe. Approximately one-third of the analytic sample had their censoring date as the date of the 15 to 90 day BP check, so follow-up time for these participants was set to be 0.1 weeks. The primary exposure was systolic and diastolic BP at the comprehensive postpartum visit.[16] We collected several potential risk factors for time to incident hypertension diagnosis, including type of HDP, maternal age at delivery, self-identified race as a proxy for having experienced racism (Black, Other, White), ethnicity (Hispanic or non-Hispanic), maternal body mass index, presence of gestational diabetes, and smoking status before delivery (current, former, or never). Chronic kidney disease was rare in our population and was not included. Family history of heart disease was not available in the data set. Race and ethnicity were captured from the electronic health record. Although ideally these capture the patient-identified race/ethnicity, it is unclear to what extent race and ethnicity may have been misassigned within the electronic health record.[17] If women had multiple HDPs diagnosed during the pregnancy, we used the most severe diagnosis available. Hierarchical severity was: (1) gestational hypertension (ICD-10-CM O13*; ICD-9-CM 642.3*), (2) preeclampsia (ICD-10-CM O14.0* and O14.9*; ICD-9-CM 642.4*), and (3) eclampsia/severe preeclampsia (ICD-10-CM O14.1* and O14.2*, O15*; ICD-9-CM 642.5* and 642.6*). We combined the categories of eclampsia and severe preeclampsia because the clinical management of these diagnoses is similar, and the group sizes were small. We defined time to the onset as the incidence of the first HDP, not necessarily the most severe.

Data Analytic Approach

Summary statistics of variable distributions were calculated. We used Cox proportional hazards models to estimate hazard ratios (HRs) for diagnosis of incident hypertension associated with systolic and diastolic BP at 15 to 90 days postpartum. We used a directed acyclic graph, constructed via expert clinical opinion, to select the minimal set of covariates needed for inclusion (Figure S1). The proportional hazards assumption was checked using graphical methods. Approximately 31% of the observations had missing values for at least 1 covariate. We assumed that these were missing at random. Therefore, we used multiple imputation with all model covariates, in addition to covariates included in the Table and specialty of the provider who measured the BP, to create 31 multiple imputed data sets. We combined the estimates from each model according to Rubin Rules. From the fitted Cox model, we estimated a cumulative incidence of hypertension diagnosis postpartum, with otherwise typical covariate values for this cohort (median for continuous; most common for categorical). Although the Cox models were fit with follow-up extending to December 31, 2019, the follow-up time for the cumulative incidence curves was estimated for only the first 12 months of follow-up after the BP check, as this was the most relevant clinical window for obstetricians. Models were fit using the R statistical computing environment,[18] including the rms package.[19] Multiple imputation was performed using the mice package.[20]

We conducted several sensitivity analyses. The first group of sensitivity analyses was based on the provider specialty when the BP check was performed. In the first sensitivity analysis, we included only patients who had a BP measurement 15 to 90 days postpartum by a provider with the specialty of Obstetrics and Gynecology, Certified Nurse Midwife, Maternal and Fetal Medicine, Family Medicine, Obstetrics, Internal Medicine (including all subspecialties), or Pediatrics. In the second sensitivity analysis, we included only those with BPs taken by obstetric caregivers.

The final sensitivity analysis checked the robustness of our findings due to the exclusion of a large proportion of otherwise eligible participants who never had a comprehensive BP measured in the 15 to 90-day window. We used inverse

Table. Description of Women Diagnosed With an Hypertensive Disorder of Pregnancy Between 2014 and 2017 by American Heart Association Blood Pressure Categories 15 to 90 Days Postpartum (N=2514)*

Characteristic	Overall N=2514	Normal (SBP <120 mm Hg, DBP <80 mm Hg) N=799	Elevated (SBP 120–129 mm Hg, DBP<80 mm Hg) N=331	Stage 1 (SBP 130–139 mm Hg or DBP 80–89 mm Hg) N=1147	Stage 2 (SBP ≥140 mm Hg or DBP ≥90 mm Hg) N=237
Age, y	30.0 (25.0–34.0)	29.0 (24.0–33.0)	29.0 (24.0–33.0)	30.0 (26.0–34.0)	31.0 (27.0–35.0)
Race					
White	1396 (56%)	470 (60%)	192 (59%)	640 (56%)	94 (40%)
Black	702 (28%)	171 (22%)	82 (25%)	332 (29%)	117 (50%)
Other	384 (15%)	146 (19%)	52 (16%)	163 (14%)	23 (9.8%)
Unknown	32	12	5	12	3
Hispanic	233 (9.4%)	80 (10%)	34 (10%)	103 (9.1%)	16 (6.8%)
Unknown	47	18	6	21	2
Year of delivery					
2014	438 (17%)	131 (16%)	53 (16%)	205 (18%)	49 (21%)
2015	557 (22%)	180 (23%)	60 (18%)	249 (22%)	68 (29%)
2016	675 (27%)	222 (28%)	95 (29%)	304 (27%)	54 (23%)
2017	844 (34%)	266 (33%)	123 (37%)	389 (34%)	66 (28%)
Median household income of ZIP code	55 950 (43 658–73 808)	53 917 (43 592–73 808)	58 115 (45 223–73 808)	56 735 (45 189–73 808)	57 133 (43 592–71 803)
Unknown	126	40	18	55	13
Marital status					
Married	1422 (59%)	465 (61%)	190 (60%)	659 (60%)	108 (48%)
Divorced	33 (1.4%)	9 (1.2%)	0 (0%)	16 (1.4%)	8 (3.5%)
Other	69 (2.9%)	17 (2.2%)	14 (4.4%)	31 (2.8%)	7 (3.1%)
Single	895 (37%)	276 (36%)	114 (36%)	401 (36%)	104 (46%)
Unknown	95	32	13	40	10
Payor					
Commercial	1375 (55%)	431 (54%)	172 (52%)	654 (57%)	118 (50%)
Government	899 (36%)	297 (37%)	119 (36%)	383 (33%)	100 (42%)
Other (including self-pay)	240 (9.5%)	71 (8.9%)	40 (12%)	110 (9.6%)	19 (8.0%)
Gestational age at delivery, wk	38.43 (37.14–39.43)	38.57 (37.14–39.71)	38.86 (37.43–39.71)	38.29 (37.00–39.29)	38.00 (37.00–39.14)
Unknown	590	195	86	241	68
Gestational age of HDP onset, wk	37.3 (34.4–39.0)	37.4 (35.1–39.1)	37.7 (34.6–39.1)	37.1 (34.0–38.7)	36.9 (33.1–38.7)
Unknown	646	212	94	263	77
Gestational diabetes	331 (13%)	88 (11%)	54 (16%)	156 (14%)	33 (14%)
Diabetes within 12 mo of delivery					
None	2327 (93%)	738 (92%)	304 (92%)	1067 (93%)	218 (92%)
Prediabetes	88 (3.5%)	36 (4.5%)	11 (3.3%)	34 (3.0%)	7 (3.0%)
Type 1	37 (1.5%)	13 (1.6%)	5 (1.5%)	15 (1.3%)	4 (1.7%)
Type 2	62 (2.5%)	12 (1.5%)	11 (3.3%)	31 (2.7%)	8 (3.4%)
Parity	0.75 (1.16)	0.63 (1.06)	0.69 (1.12)	0.80 (1.19)	1.02 (1.33)
Unknown	413	127	63	175	48
BMI, kg/m^2	34 (30–40)	33 (29–38)	34 (30–39)	35 (30–40)	36 (30–42)
Unknown	134	39	13	66	16
Smoking status within 12 mo of delivery					
Never	1576 (63%)	514 (64%)	209 (63%)	717 (63%)	136 (58%)
Current	558 (22%)	169 (21%)	76 (23%)	247 (22%)	66 (28%)
Former	372 (15%)	114 (14%)	46 (14%)	178 (16%)	34 (14%)
Unknown	8	2	0	5	1

(*Continued*)

Table. Continued

Characteristic	Overall N=2514	Normal (SBP <120 mm Hg, DBP <80 mm Hg) N=799	Elevated (SBP 120–129 mm Hg, DBP<80 mm Hg) N=331	Stage 1 (SBP 130–139 mm Hg or DBP 80–89 mm Hg) N=1147	Stage 2 (SBP ≥140 mm Hg or DBP ≥90 mm Hg) N=237
Type of hypertensive disorder of pregnancy					
Gestational hypertension	1444 (57%)	431 (54%)	215 (65%)	664 (58%)	134 (57%)
Preeclampsia	460 (18%)	161 (20%)	60 (18%)	198 (17%)	41 (17%)
Eclampsia/severe preeclampsia	610 (24%)	207 (26%)	56 (17%)	285 (25%)	62 (26%)
Had blood pressure check within 14 d postpartum	498 (20%)	153 (19%)	64 (19%)	229 (20%)	52 (22%)
SBP within 14 d postpartum, mm Hg	134 (124–146)	129 (121–139)	133 (123–145)	136 (128–148)	144 (133–151)
Unknown	2016	646	267	918	185
DBP within 14 d postpartum, mm Hg	85 (77–92)	81 (73–90)	87 (74–93)	87 (80–93)	87 (78–94)
Unknown	2016	646	267	918	185
American Heart Association categories of blood pressure in adults within 14 d postpartum					
Normal (SBP <120 mm Hg, DBP <80 mm Hg)	61 (12%)	29 (19%)	13 (20%)	17 (7.4%)	2 (3.8%)
Elevated (SBP 120–129 mm Hg, DBP <80 mm Hg)	46 (9.2%)	22 (14%)	6 (9.4%)	15 (6.6%)	3 (5.8%)
Stage 1 (SBP 130–139 mm Hg or DBP 80–89 mm Hg)	243 (49%)	74 (48%)	26 (41%)	118 (52%)	25 (48%)
Stage 2 (SBP ≥140 mm Hg or DBP ≥90 mm Hg)	148 (30%)	28 (18%)	19 (30%)	79 (34%)	22 (42%)
Unknown	2016	646	267	918	185
SBP 15–90 d postpartum, mm Hg	123 (114–132)	111 (106–115)	123 (121–126)	130 (122–135)	146 (141–153)
DBP 15–90 d postpartum, mm Hg	79 (72–85)	70 (66–75)	74 (70–77)	84 (81–87)	94 (91–100)
Unknown	1	0	0	1	0
Diagnosis of hypertension after comprehensive visit	315 (13%)	56 (7.0%)	33 (10.0%)	166 (14%)	60 (25%)

BMI indicates body mass index; DBP, diastolic blood pressure; HDP, hypertensive disorder of pregnancy; and SBP, systolic blood pressure.
*Six participants not shown in the table due to missing DBP and inability to determine American Heart Association category.

probability weighting to upweight participants who had a low probability of having a comprehensive BP measured in the 15 to 90-day window, to better target the Cox models to represent both women who had a comprehensive BP and those who did not. Variables included in the model predicting the probability of having a comprehensive BP measured in the 15 to 90-day window included all covariates in the main models, as well as institution where care was received, year of delivery, payer, median household income of maternal ZIP code of residence, marital status, parity, diabetes status 12 months before delivery, specialty of provider who measured the BP, and gestational age of HDP onset. The WeightIt package was used for the inverse probability weighting.[21]

Programming code can be made available via request to the corresponding author.

Institutional Review Board Statement

This study was approved by the institutional review boards at both health systems, as well as by Auburn University, where the data analysis was conducted. No informed consent was required.

RESULTS

There were 9230 individuals in the original cohort. Of those, 5657 delivered between 2014 and 2017. After applying the remaining exclusion criteria, the final sample size for this analysis was 2520 (Figure 1). Approximately 39% (1584) of individuals diagnosed with an HDP between 2014 and 2017 who were otherwise eligible for the study did not have a documented BP check by any clinician at 15 to 90 days postpartum in either of the health care systems. For details about characteristics of included versus excluded participants (Figure S2). Included participants were slightly older, less likely be Hispanic, but more likely to be White, married, have gestational diabetes, live in higher income ZIP codes, and have private insurance. The median (1st quartile, 3rd quartile) follow-up time after the 15 to 90 days postpartum BP check was 9.9 months (0.02 months, 27.3 months). Maximum follow-up time was 64.3 months (over 5 years).

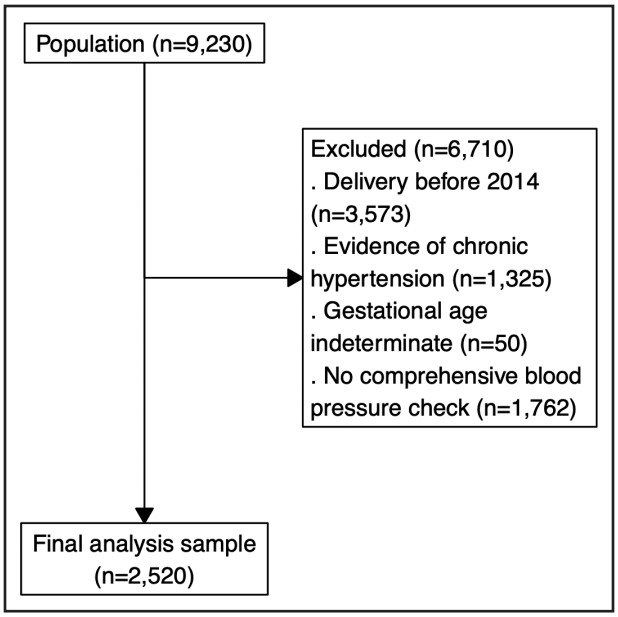

Figure 1. Study flowchart of included patients for analysis of incident hypertension after an hypertensive disorder of pregnancy (HDP).

Summary statistics according to AHA BP ranges at 15 to 90 days postpartum are reported in the Table.[16] Only 32% (799/2514) had BPs in the normal range and the majority (55%) had BPs in the range that would be classified as of Stage 1 or 2 Hypertension if similar or higher readings had been obtained on a second occasion. Twenty percent also had a clinical BP measurement recorded within the first 14 days postpartum. Among those who did, almost 80% had BPs in the Stage 1 or 2 hypertension range. Thirteen percent of the population (316 participants) were diagnosed with incident hypertension after the 15 to 90-day BP measurement during the entire follow-up period.

The HR of developing incident hypertension was statistically significantly higher for those with elevated (140 versus 120 mm Hg) systolic BP (HR, 1.81 [95% CI, 1.46–2.24]) but not for those with elevated (90 versus 70 mm Hg) diastolic BP (HR, 1.18 [95% CI, 0.88–1.58]). See Table S4 and Figure S2 for HRs and 95% CIs for all model covariates. Eclampsia/severe preeclampsia versus gestational hypertension, older maternal age, Black versus White race, and current smoking were associated with a higher hazards of incident hypertension. HR for other variables included in the model are available in Table S4 and Figure S2. No covariates demonstrated strong deviations from the proportional hazards assumption (Figure S5). In the sensitivity analyses that were restricted to only women whose comprehensive visit BP was performed by: (1) an obstetric or primary care specialty provider, or (2) an obstetric provider, the results were similar (Table S3 and Figure S3). In a sensitivity analysis in which we used inverse probability weighting to target the population of otherwise eligible individuals, including those who never had a 15 to 90 day BP check, the results were similar to the primary analysis (HR for systolic blood pressure 140 versus 120 mm Hg 1.96 [95% CI 1.49–2.56]; HR for DBP 90 versus 70 mm Hg 1.10 [95% CI 0.77–1.55]; Table S4 and Figure S4).

Figure 2 shows the modeled cumulative incidence of hypertension within 12 months after the 15 to 90 day BP check for specific postpartum BPs categories: optimal, at-risk, Stage 1 hypertension and Stage 2 hypertension.[16,22] For the figure, we chose a time period of 12 months after the BP check for visualization, since by current guidelines, all women should have had a primary care transition in that time period. These plots were created based on the Cox models fit in the primary analysis, which did allow for follow-up later than 1 year (ie, no administrative censoring at 1 year). However, we felt that showing the estimates of cumulative incidences for 1 year after the postpartum BP check would be a clinically relevant time period. The other covariates in the model were set at the typical values in our sample (ie, median values for continuous and most common values for categorical variables). For women with a BP in the optimal range (110/65 mm Hg), the risk of being diagnosed with hypertension by 12 months after the 15 to 90 day BP measurement was 4.5% (95% CI, 2.8%–6.1%). For women with a systolic BP of 140 mm Hg and diastolic BP of 90 mm Hg, the risk was 12.9% (95% CI, 8.4%–17.2%).

DISCUSSION

Among women diagnosed with HDPs at 2 academic health systems, >1 in 10 women developed incident hypertension after delivery. Higher systolic BP at the 15 to 90 days postpartum was associated with a greater risk; diastolic BP was not significantly associated with incident hypertension. The proportion of individuals without a 15 to 90 days postpartum BP was high (40%) despite our inclusion of any BP completed during any clinical interaction in the 2 health systems. Over 90% of the 15 to 90 days postpartum BP evaluations were conducted by obstetric providers. During the study period, the early BP screening recommendation for individuals who experience HDPs was relatively new, the guideline having been first published in November 2013.[23] Our findings are consistent with other studies in that only about 40% to 60% of patients with HDPs have a postpartum BP check during the first 90 days postpartum.[24–26] Among women who had a 15 to 90-day BP check, only 20% had an early (<15 days) BP check as recommended.

There is relatively little data in US populations about the risk of developing hypertension during the first year after a birth complicated by an HDP. In a Danish cohort (1995–2007), the hazards of developing hypertension

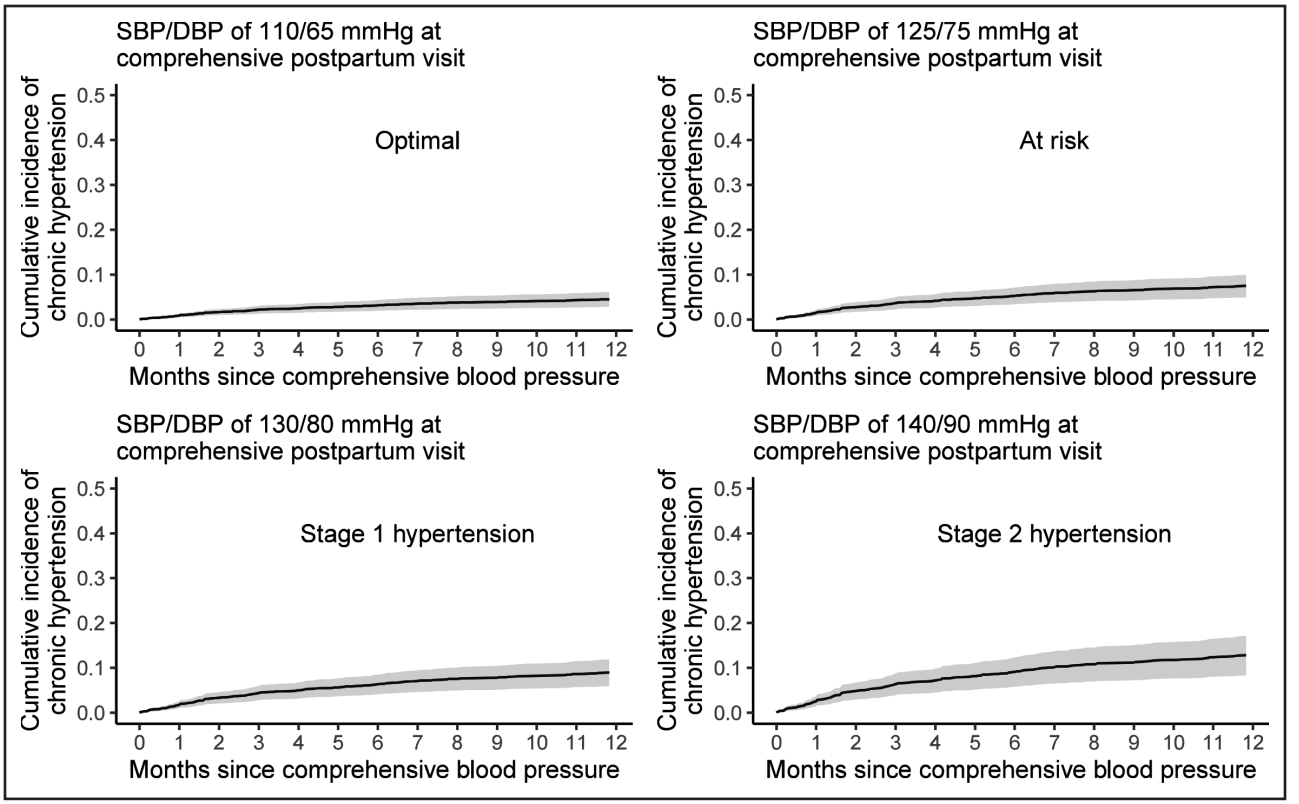

Figure 2. Cumulative incidences and 95% CIs for diagnosis of incident hypertension after an hypertensive disorder of pregnancy (HDP; n=2520, m=316 events), by postpartum blood pressure (BP) category.
Other covariates were set to typical values in the data set, so these predicted cumulative incidences are for a hypothetical woman with a nonsevere clinical profile. For example, these predictions are for a non-Hispanic White woman age 29 with preeclampsia, no gestational diabetes, a never smoker, and body mass index (BMI) of 34.7 kg/m^2.

in the year after delivery was 12 to 25-fold higher than for individuals without an HDP. The hazards ratios were lower for later time points, suggesting that the first year after pregnancy may be a particularly common time to diagnose hypertension.[27] In a Scottish study (1951–1970) increasing severity of the HDP was associated with higher odds of incident hypertension was (1.95 for gestational hypertension and 2.97 for preeclampsia/eclampsia).[28] We found increased hazards among Black versus White participants, and there are very little data investigating these associations.[29,30] Our group has also demonstrated that early BP screening is associated with increased detection of other incident cardiovascular risk factors.[31]

The strengths of our study include a large sample size allowing us to follow patients with HDPs for a median of 9.9 months after measuring a BP 15 to 90 days postpartum. The study used routinely collected electronic health data and thus is reflective of real-world clinical practice and applicable to others seeking to use such data to perform population surveillance and quality improvement. Our population was diverse by race, ethnicity, zip code median income, clinical risk factors for hypertension and insurance status, which is rare in studies of HDPs.[30]

This study was limited by the retrospective nature of this electronic health data. Due to this, we were limited to BP measurements and other data that were ascertained during the course of typical care in 2 academic health systems. Therefore, about 40% of our analytic population was excluded from the primary analysis because they never had a BP check reported in 15 to 90 days postpartum. Other studies have also found that up to 40% of individuals with HDPs never return for a postpartum visit leading, a proportion similar to what we found in our study.[9] In addition, patients who delivered in these health systems may have been transferred from geographically distant areas in the state specifically because of their diagnosis of HDP and may have subsequently received postpartum care and timely BP back in their own community not affiliated with the health systems leading to missing BP measurements for those individuals. There is also a small chance that BP may have been measured during a visit but not recorded in the chart. To maximize our included sample, we included all BPs measured in the time period and not just primary care and obstetric measurements. We also presented differences between the excluded versus included population in our supplement. Individuals included in our analysis were older, more

likely to be White, less likely to be Hispanic, more likely to be married, more likely to be commercially insured, and less likely to smoke than individuals excluded from the study. Many of these differences are associated with better access to health care in general and likely impacted these individuals' ability to receive recommended postpartum care.[32,33] We mitigated this limitation by performing a sensitivity analysis using inverse probability weighting to target the entire potentially eligible set of participants, which included those who had a BP measured 15 to 90 days postpartum and those who did not have BP measured in this time frame. However, the results for this entire set of participants were similar to the results for the primary analysis. Half of the participant exclusions were due to preexisting hypertension, which likely explains the differential distribution of CVD risk factors (ie, age and smoking) between those included versus not included in the primary analysis.

Another limitation is that our outcome of incident hypertension was a clinical diagnosis that relied upon ICD-10-CM codes. Use of these codes to identify hypertension is consistent with expected population estimates of hypertension and is frequently used as an outcome in studies of long-term risk after HDP.[34,35] The potential for misclassification of HDPs by ICD-10-CM codes also exists; however, validation studies have shown that these codes used together have very high (>95%) specificity and sensitivity for any HDP, as well as very high specificity for each subcategory.[36] We felt that using BP measurements to define the outcome would have been subject to more bias since we do not have contextual information such as medication use to help us interpret these BPs. The hazards of receiving an ICD-10-CM diagnosis of hypertension may be impacted by clinical decision-making. For example, older women may have been more likely to be given the diagnosis of hypertension by their providers than younger women with the same BP measurements. This study may not be generalizable outside the US South or to patients who deliver at nonacademic hospitals.

Our study has several important implications for future policy related to appropriate postpartum care. First, current clinical guidelines for postpartum BP evaluation in individuals with HDP were not consistently applied. There are health system level barriers (eg, insufficient patient education or difficulty accessing appointments) and patient-level barriers (eg, transportation or caring for a newborn) to receiving this care.[33,37] Opportunities exist for the use of electronic health data to identify eligible patients and offer BP screening after an HDP when it has not yet occurred. This could be paired with programs to remove barriers for patients, such as home monitoring, telehealth, and home visitors.[24,38] Second, given the significant numbers of individuals diagnosed with incident hypertension regardless of the severity of HDP or BP measurement postpartum, preventive guidelines for long-term health should be consistent and should prioritize early lifestyle modification and control of BP and other CVD risk factors. All providers who see patients who have experienced HDPs should be aware of potential risks and should identify and manage hypertension early. Future research should explore preventive interventions to improve hypertension management for individuals who experience HDPs, ideally codesigned with patients so as to address the unique needs and experiences of the postpartum period.[39,40]

PERSPECTIVES

Postpartum visits, including BP checks, have been recommended for some time by ACOG and the AHA. However, in our cohort, these screenings were not being completed for many patients who have HDPs. Though higher systolic BPs measured in the postpartum period were associated with a higher hazard of being diagnosed with hypertension after the postpartum BP check, we found that even among participants with ideal BPs of 110/65 and no history of chronic hypertension, 1 in 20 were diagnosed with hypertension within the first year postpartum. Therefore, it is important for providers of all kinds, especially obstetric and primary care providers, to screen patients for a history of HDP, to educate patients about their cardiovascular risk, and to recommend BP screening within the year postpartum to diagnose and optimally manage any hypertension that occurs.[41] Evidence-based guidelines agreed upon and implemented by obstetric and primary care providers are needed.

ARTICLE INFORMATION

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Disclosures

None.

Supplemental Material

Tables S1–S5
Figures S1–S6

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