Early postpartum blood pressure screening is associated with increased detection of cardiovascular risk factors in women with hypertensive disorders of pregnancy

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ABSTRACT

Background Hypertensive disorders of pregnancy (HDP), including gestational hypertension, preeclampsia, and eclampsia, are risk factors for cardiovascular (CV) disease. Guidelines recommend that women with HDP be screened for the development of hypertension (HTN) within 6-12 months postpartum. However, the extent to which this early blood pressure (BP) screening is being performed and the impact on detection of CV risk factors is unknown.

Methods Women with HDP and without pre-existing hypertension (HTN) who had at least 6 months of clinical follow-up were categorized by postpartum BP screening status: early BP screen (6-12 months after delivery) or late BP screen (≥12 months after delivery). Multivariable logistic regression identified factors associated with early screening. Multivariable Cox proportional hazards modeling examined the association between early screening and detection of incident CV risk factors: HTN, prediabetes, diabetes mellitus type 2, or hyperlipidemia.

Results Among 4194 women with HDP, 1172 (28%) received early BP screening. Older age, pre-existing hyperlipidemia, diabetes, sickle cell disease, hypothyroidism, gestational diabetes, and delivery during or after 2014 were independently associated with early BP screening, whereas Hispanic ethnicity was associated with late BP screening. Early BP screening was most commonly performed at a primary care visit. After a median follow-up of 3.7 years, 1012 (24%) women had at least 1 new risk factor detected. Even after adjustment for baseline risk, women receiving early BP screening had a significantly higher rate of incident CV risk factor detection than women receiving late BP screening (56% vs 28%; adj. HR 2.70, 95%CI: 2.33-3.23, $P < .001$).

Conclusions Early postpartum BP screening was performed in a minority of women with HDP, but was associated with greater detection of CV risk factors. More intensive postpartum CV screening and targeted interventions are needed to optimize CV health in this high-risk population of women with HDP. (Am Heart J 2024;273:130–139.)

Abbreviations

AHA	American Heart Association
ASA	American Stroke Association
BP	blood pressure
CV	cardiovascular
DM2	diabetes mellitus, type 2
EHR	electronic health record
HDP	hypertensive disorders of pregnancy
HLD	hyperlipidemia
HTN	hypertension

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Background

Hypertensive disorders of pregnancy (HDP), which include gestational hypertension, preeclampsia, and

eclampsia, are associated with the development of maternal cardiovascular (CV) disease later in life.[1-10] Preeclampsia and eclampsia affect approximately 2%-8% of pregnancies and gestational hypertension occurs in 3%-14% of pregnancies.[9, 11-13] The overall rate of HDP has increased 72% in the last 2 decades and is a leading cause of maternal morbidity and mortality.[14-16] Compared to women without HDP, women with HDP have twice the risk for developing essential hypertension (HTN), which is the predominant risk factor for heart disease and stroke in women.[17, 18] Therefore, HDP can be considered an early warning sign for increased CV risk and is included as a "risk enhancer" in the current American College of Cardiology and American Heart Association (AHA) prevention guidelines.[19] However, this non-traditional CV risk factor remains under-appreciated or unrecognized by patients and providers.

To promote increased awareness, the AHA and American Stroke Association (ASA) have recommended that women with a history of preeclampsia or eclampsia be evaluated for incident HTN starting 6 months to 1 year postpartum (*Class 2a; Level of Evidence C*).[20] However, the degree to which this screening recommendation is being followed in clinical practice and the impact on clinical outcomes, such as the detection of incident HTN and other CV risk factors, is unknown. We hypothesized that early blood pressure (BP) screening in women with HDP is inconsistent in clinical practice and represents an opportunity for targeted intervention. To study this, we analyzed a large regional cohort of women with HDP to investigate the frequency of early BP screening and whether CV risk factor identification varies by screening status.

Methods

Study design and population

The Carolinas Collaborative is a partnership between the National Institutes of Health's Clinical and Translational Science Award (CTSA) programs in North and South Carolina. This collaborative serves as a data resource that harmonizes electronic health data across institutions to expedite clinical research. Using the common data model (CDM) of the Carolinas Collaborative, we identified women with a HDP and delivery at Duke University or the University of North Carolina at Chapel Hill (UNC) between January 1, 2007 and December 31, 2017. Our primary objective was to assess the timing of BP screening among women with HDP who had at least 6 months of clinical follow-up and then evaluate the association of early versus late BP screening with incident CV risk factor detection.

Women of childbearing age with HDP and one or more BP measurements during at least 6 months of follow-up were included. In women with multiple pregnancies complicated by a HDP, the first pregnancy served as the index pregnancy. We excluded women with: 1) pre-existing chronic hypertension; 2) a HDP diagnosis greater than 6 months before or 6 weeks after the date of delivery; and 3) less than 6 months of follow-up (Supplemental Table 1). In women with more than one HDP diagnosis during the index pregnancy, the most severe HDP diagnosis was used. Patients were categorized according to postpartum BP screening status. The 'early screen' population was defined as having a BP measurement within 6 to 12 months after delivery (as recommended in the AHA/ASA guidelines), while those with a BP measured after 12 months postpartum comprised the 'late screen' population. The primary endpoint was a composite of incident CV risk factors, which were defined as a new diagnosis of HTN, prediabetes, diabetes mellitus, type 2 (DM2), or hyperlipidemia (HLD). Secondary endpoints included the incidence of individual CV risk factors. Clinical outcomes were collected through June 30, 2019. Those women with pre-existing CV risk factors were excluded from the analysis of the same incident risk factor. Additionally, individuals with pre-existing diabetes mellitus (type 1 or 2) were excluded from the analysis of incident prediabetes and DM2, but included for evaluation of incident HTN or HLD.

Statistical analysis

Descriptive data are presented as frequencies and percentages for categorical variables and mean ± standard deviation or median with 25th and 75th interquartile range (IQR) for continuous variables, as appropriate. Differences in continuous and categorical variables were assessed using the Wilcoxon rank-sum test and the chi-square test, respectively. Blood pressure monitoring was reported as rate per patient-year. Multivariable logistic regression modeling was used to assess the factors associated with early BP screening. The covariates included in the model were: maternal age at delivery, race, ethnicity, insurance coverage, pre-existing conditions (HLD, diabetes, prediabetes, hypothyroidism, sickle cell disease), subtype of HDP, concomitant gestational diabetes, preterm delivery (prior to 37 weeks gestation), route of delivery, delivery during or after 2014 (the year of guideline and EHR implementation) and comprehensive postpartum obstetrics visit, which is recommended to occur no later than 12 weeks after birth. Unadjusted cumulative incidence rates were estimated from 6 months to 5 years after delivery; screening group differences were tested using the log-rank test. Pre-existing CV risk factors were not included in the estimates of incident CV risk factors. Cox proportional hazards regression models were used to examine the associations between early or late postpartum BP assessment status and detection of CV risk factors. The following covariates were included in the outcome models: maternal age at delivery, race, ethnicity, insurance status, delivery during or after 2014, pre-existing

conditions (prediabetes, diabetes, HLD, hypothyroidism, sickle cell disease), subtype of HDP, gestational diabetes, pre-term delivery, postpartum comprehensive visit, early vs. late screening status, systolic BP at screening, diastolic BP at screening, and provider specialty performing screening. Adjusted hazard ratios and 95% confidence intervals (CI) are reported. Tests of statistical significance were conducted at the 2-tailed alpha level of 0.05. Statistical analyses were performed using the SAS version 9.4 software package (SAS Institute, Inc., Cary, North Carolina).

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Results

Among 9,782 women with HDP, 4,194 (43%) had at least 6 months of follow-up postpartum and at least 1 BP measurement that served as the screen for incident HTN (Figure 1). Of these, 1,172 (27.9%) women received early BP screening within 6 to 12 months postpartum, while 3,022 (72.1%) women had late BP screening (after 12 months postpartum). Women screened early were older, more frequently Black, non-Hispanic, and had a greater burden of pre-existing CV risk factors, specifically prediabetes, diabetes, and HLD (Table 1). Compared to women screened late, women undergoing early screening were also more likely to have hypothyroidism and sickle cell disease. There were no statistically significant differences in gestational age of onset or HDP severity between the early and late screening groups. Compared to the late screen population, the early screen population had higher gravidity, as well as higher rates of gestational diabetes, pre-term delivery and Cesarean delivery. More than half of women in the early screen group attended the comprehensive postpartum obstetrics visit (58%) compared to approximately a third of women in the late screen group (37%), $P < .0001$. Early screening was significantly more frequent among women who delivered during or after 2014, which coincided with both the publication of the AHA/ASA guideline[20] and the implementation of a new electronic health record (EHR) at both institutions.

After multivariable adjustment, pre-existing HLD (OR 3.72, 95%CI: 1.81-7.63), sickle cell disease (OR 3.71, 95%CI: 1.80-7.62), hypothyroidism (OR 2.67, 95%CI: 1.97-3.64), gestational diabetes (OR 1.78, 95%CI: 1.46-2.18), pre-existing diabetes (OR 1.50, 95%CI: 1.09-2.07), delivery during or after 2014 (OR 1.44, 95%CI: 1.33-1.56), government insurance at delivery (OR 1.25, 95%CI: 1.02-1.53) and older age (OR: 1.02, 95%CI: 1.00-1.03) were independently associated with early BP screening, whereas Hispanic ethnicity was associated with late BP screening (OR: 0.65, 95%CI: 0.45-0.93). Delivery during or after 2014 had the strongest association with early screening ($X^2 = 74.7$), followed by hypothyroidism ($X^2 = 39.4$), and gestational diabetes ($X^2 = 31.7$), all $P < .001$.

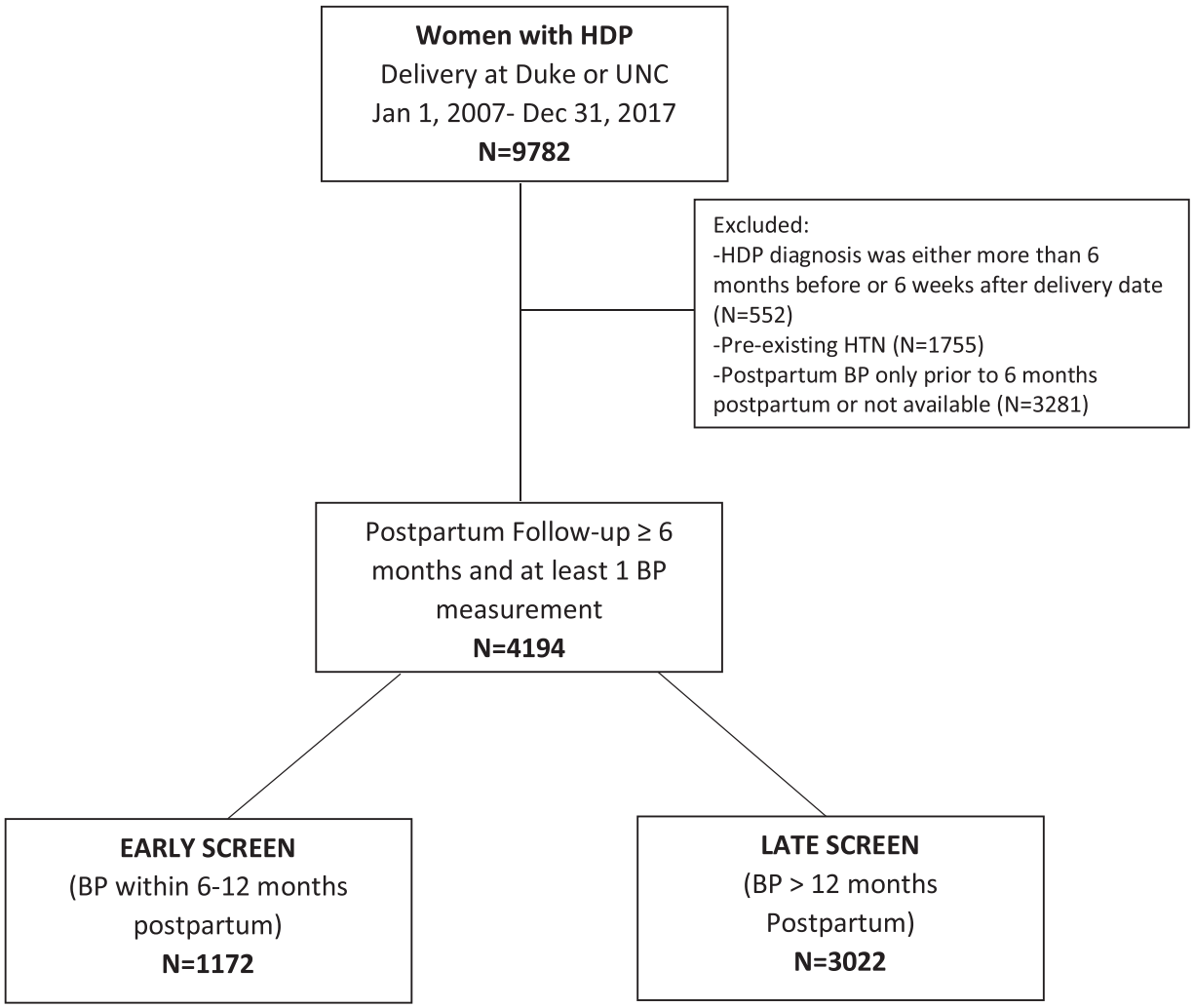
Blood pressure at the time of screening was higher among women receiving early screening compared to late screening: 123/77 vs. 122/75, ($P = .04$ for systolic BP, $P < .0001$ for diastolic BP). After 1 year postpartum, blood pressure monitoring was significantly more frequent in women screened early compared to women screened late: 4.3 vs. 2.0 assessments per year, $P < .001$. The early BP screening was most commonly completed at a primary care visit, while late BP screening was most frequently performed at an obstetrician-gynecologist visit (Figure 2). Women receiving early BP screening had a significantly higher rate of postpartum primary care follow-up with 3.9 visits per year compared to 1.6 visits per year among those screened late ($P < .001$). This suggests that early screening may be a surrogate for more vigilant postpartum primary care.

After median follow-up of 3.7 years (IQR: 2.1-6.1), 1,012 (24%) women experienced the primary composite endpoint. The cumulative incidence rate for new risk factor detection was 56.4% among those screened early and 28.3% for those screened late ($P < .001$) (Figure 3). After multivariable adjustment, women receiving early BP screening had a nearly 3-fold higher rate of detection of incident CV risk factors compared to women receiving late BP screening (adj. HR 2.70, 95%CI: 2.33-3.23, $P < .001$). In addition to early screening, age, Black race, government insurance, pre-existing diabetes, gestational diabetes, primary care follow-up, diastolic BP >80 mmHg at screening, and delivery during or after 2014 were also significantly associated with an increased CV risk factor detection (Figure 4). Hypertension was the most frequent incident CV risk factor detected (cumulative incidence 26.2%), followed by prediabetes (6.6%), HLD (5.7%), and DM2 (5.2%). After adjustment, the incidence of each individual CV risk factor was significantly greater among women screened early compared to those screened late, except for hyperlipidemia (Figure 5).

Discussion

In this large, diverse regional cohort of women with HDP and at least 6 months of clinical follow-up postpartum, only a minority underwent early BP screening in

Figure 1. Consort diagram – Diagram of included and excluded patients. BP, blood pressure.



accordance with guideline recommendations for the detection of incident HTN. Those receiving early BP screening were older with more pre-existing CV risk factors and other concomitant pregnancy complications compared to those women screened a year or more after delivery. However, even after controlling for these factors, women screened early had a higher rate of incident CV risk factor detection than those screened late. A significantly greater number of women receiving early BP screening delivered during or after 2014, which may reflect the impact of AHA/ASA guideline recommendations and EHR implementation on postpartum clinical care. This study reflects real-world clinical practice and identifies opportunities for improvement in the postpartum care of women with HDP. Further efforts are needed to systematically screen women with HDP and improve the early detection of CV risk factors. Earlier and more frequent postpartum follow-up in these high-risk women with HDP is critical for promoting lifestyle and therapeutic interventions that can alter CV disease trajectory and reduce future morbidity and mortality in women.

The need for frequent blood pressure (BP) monitoring during pregnancy in women with chronic hypertension and those who develop a HDP is well established.[21,22] However, the processes of care and treatment following the hypertensive disorders of pregnancy are a relatively understudied area of women's health.[23] This study describes the current management that women with HDP are receiving in the postpartum period. Only 28% of women with greater than 6 months of follow-up had a BP measurement that constituted an early screening in the year after delivery. Nearly 40% of the early screening was performed at a primary care encounter. This may reflect the continuation of care that women were already receiv-

Figure 2. Specialty performing early and late blood pressure screening. Pie charts of specialty visits during which early (left) and late (right) blood pressure screening occurred for women with HDP.

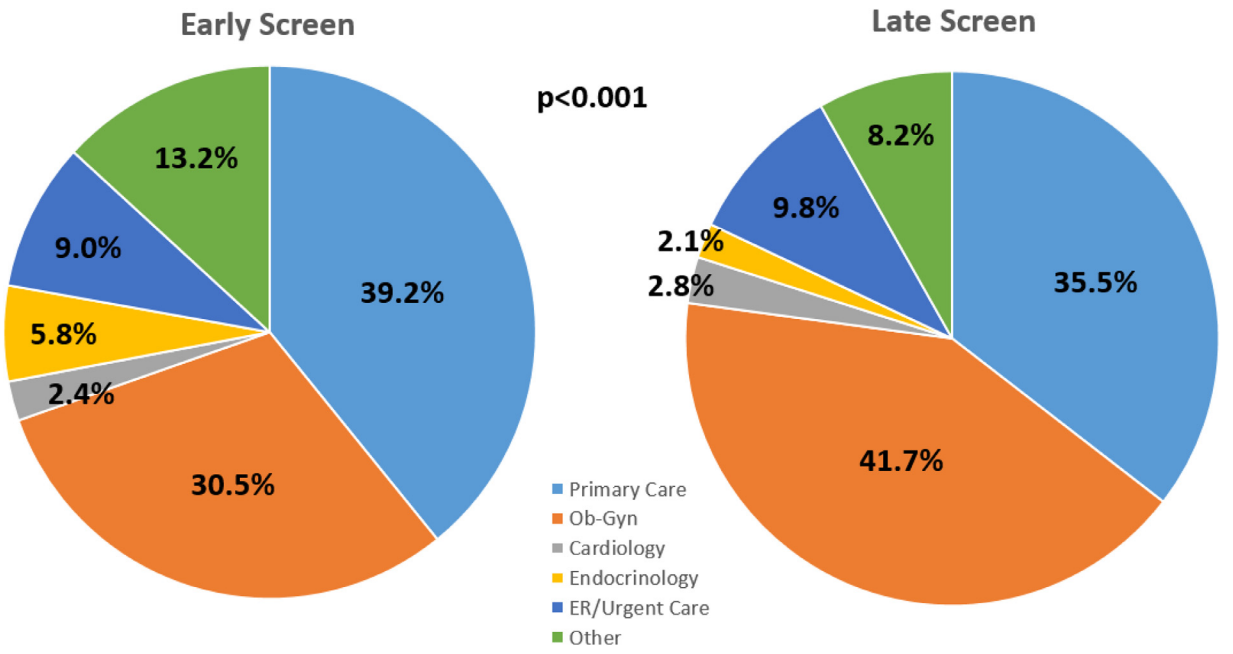


Figure 3. Cumulative incidence of cardiovascular risk factors by screening group. The incidence of cardiovascular risk factors in women with HDP that underwent early blood pressure screening compared to those that received late blood pressure screening. DM2, diabetes mellitus, type 2; HTN, hypertension.

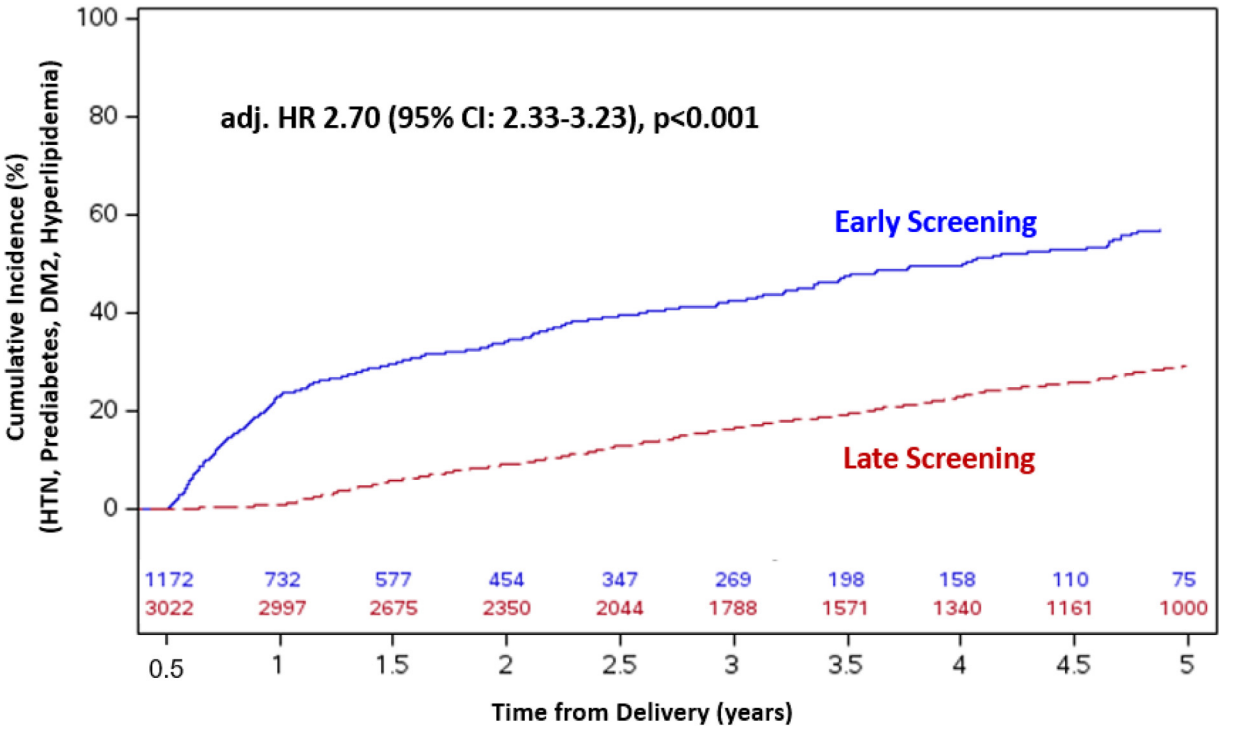


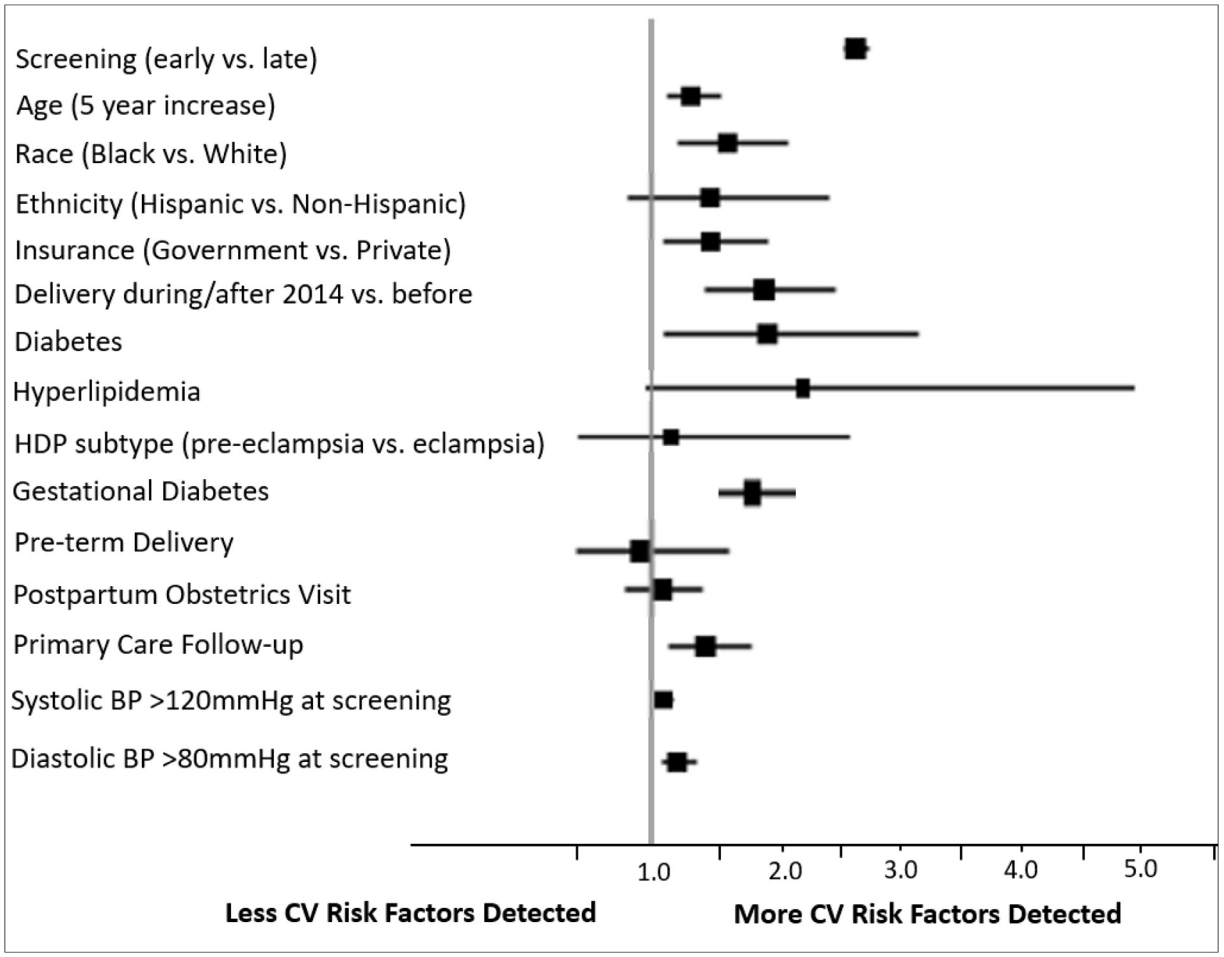
Table 1. Patient Characteristics

	All Women (n = 4,194)	Early Screen (n = 1,172)	Late Screen (n = 3,022)	*P*-value
Patient Characteristics at Delivery				
Age (yrs)	28.6 ± 6.3	29.5 ± 6.2	28.3 ± 6.3	**<.001**
Race (Black)	1,356 (32.3%)	403 (34.4%)	953 (31.5%)	**<.001**
Hispanic	584 (13.9%)	98 (8.4%)	486 (16.1%)	**<.001**
Body mass index (kg/m^2)	32.8 ± 7.6	33.0 ± 7.8	32.6 ± 7.5	.23
Marital status (married)	1,799 (53.1%)	543 (51.8%)	1,256 (53.7%)	.10
Insurance:				**<.001**
Private/Commercial	1,148 (27.4%)	452 (38.6%)	696 (23.0%)	
Government	1,078 (25.7%)	421 (35.9%)	675 (21.7%)	
Self-pay	33 (0.8%)	15 (1.3%)	18 (0.6%)	
Not reported	1,935 (46.1%)	284 (24.2%)	1,651 (54.6%)	
Median Household Income (10 K units)*	5.4 (4.4, 7.2)	5.2 (4.4, 7.2)	5.5 (4.4, 7.2)	.37
Medical History at Delivery				
Hyperlipidemia	42 (1.0%)	28 (2.4%)	14 (0.5%)	**<.0001**
Prediabetes	118 (2.8%)	48 (4.1%)	70 (2.3%)	**.002**
Diabetes mellitus, type 2	82 (2.0%)	53 (4.5%)	29 (1.0%)	**<.0001**
Diabetes mellitus, type 1	73 (1.7%)	48 (4.1%)	25 (0.8%)	**<.0001**
Smoking Status:				.20
Never	2,337 (57.7%)	644 (56.0%)	1,693 (58.4%)	
Current	1,136 (28.0%)	326 (28.3%)	810 (27.9%)	
Former	579 (14.3%)	181 (15.7%)	398 (13.7%)	
Hyperthyroidism	9 (0.2%)	6 (0.5%)	3 (0.1%)	**.02**
Hypothyroidism	224 (5.3%)	116 (9.9%)	108 (3.6%)	**<.0001**
Renal disease	8 (0.2%)	4 (0.3%)	4 (0.1%)	.23
Sickle Cell Disease	41 (1.0%)	29 (2.5%)	12 (0.4%)	**<.0001**
Pregnancy Characteristics				
Hypertensive Disorders of Pregnancy:				**<.0001**
Gestational hypertension	2,168 (51.7%)	629 (53.7%)	1,539 (50.9%)	
Preeclampsia	1,282 (30.6%)	379 (32.3%)	903 (29.9%)	
Severe preeclampsia	685 (16.3%)	139 (11.9%)	546 (18.1%)	
Eclampsia	59 (1.4%)	25 (2.1%)	34 (1.1%)	
Preeclampsia + Severe Preeclampsia + Eclampsia	2,026 (48.3%)	543 (46.3%)	1,483 (49.1%)	.11
Gestational onset of HDP (wk)	36.8 ± 3.5	36.7 ± 3.5	36.8 ± 3.6	.43
Systolic BP (at time of HDP diagnosis)	130.6 ± 16.7	131.0 ± 17.1	130.3 ± 16.4	.36
Diastolic BP (at time of HDP diagnosis)	79.3 ± 14.0	79.5 ± 14.3	79.2 ± 13.9	.51
Gestational diabetes	773 (18.4%)	330 (28.2%)	443 (14.7%)	**<.0001**
Pre-term delivery (<37 wk)	155 (3.7%)	63 (5.4%)	92 (3.0%)	**.0003**
Gestational age at delivery (wk)	37.8 ± 2.8	37.6 ± 2.7	37.9 ± 2.9	**<.0001**
Gravidity	2.5 ± 1.9	2.7 ± 1.9	2.4 ± 1.8	**.0001**
Cesarean Delivery	1,780 (42.4%)	546 (46.6%)	1,234 (40.8%)	**.0007**
Delivered during or after 2014	2,316 (55.2%)	934 (79.7%)	1,382 (45.7%)	**<.0001**
Comprehensive OB visit (postpartum)	1,784 (42.5%)	679 (57.9%)	1,105 (36.6%)	**<.0001**

Values are presented as N (%) or mean ± standard deviation unless otherwise noted.
*Median (IQR: 25th, 75th percentile).BP, blood pressure; HDP, hypertensive disorder of pregnancy; HTN, hypertension; OB, obstetrics.

ing due to a medical condition that predated the index pregnancy with HDP and subsequently resulted in the detection of an incident CV risk factor. Conversely, 42% of late BP screenings were conducted at an obstetrics-gynecology visit. It is unknown if these visits were for an annual women's health exam, a subsequent pregnancy or another reason, but it does indicate that, along with primary care providers, obstetrics-gynecology clinicians are performing the majority of postpartum BP screening in women with HDP. Obstetrics-gynecology providers may be less familiar with the management of CV risk factors, but are uniquely positioned to identify CV risk given their role in women's reproductive care and ensure that patients are transitioned to primary care or referred for other appropriate management during the postpartum period.[24] Cardiology providers performed less than 3% of both the early and late BP screenings, which suggests that use of cardio-obstetrics clinics dedicated to the monitoring of high-risk women with HDP during and after pregnancy was underutilized and is a potential target for intervention. In June 2018, the AHA and the American College of Obstetrics and Gynecologists (ACOG) issued a presidential advisory promoting risk identification and reduction of CV disease in women through collaborations between cardiologists and obstetricians and gynecologists.[25] A multidisciplinary approach involving pri-

Figure 4. Forrest plot of factors associated with postpartum CV risk factor detection.
CV, cardiovascular.

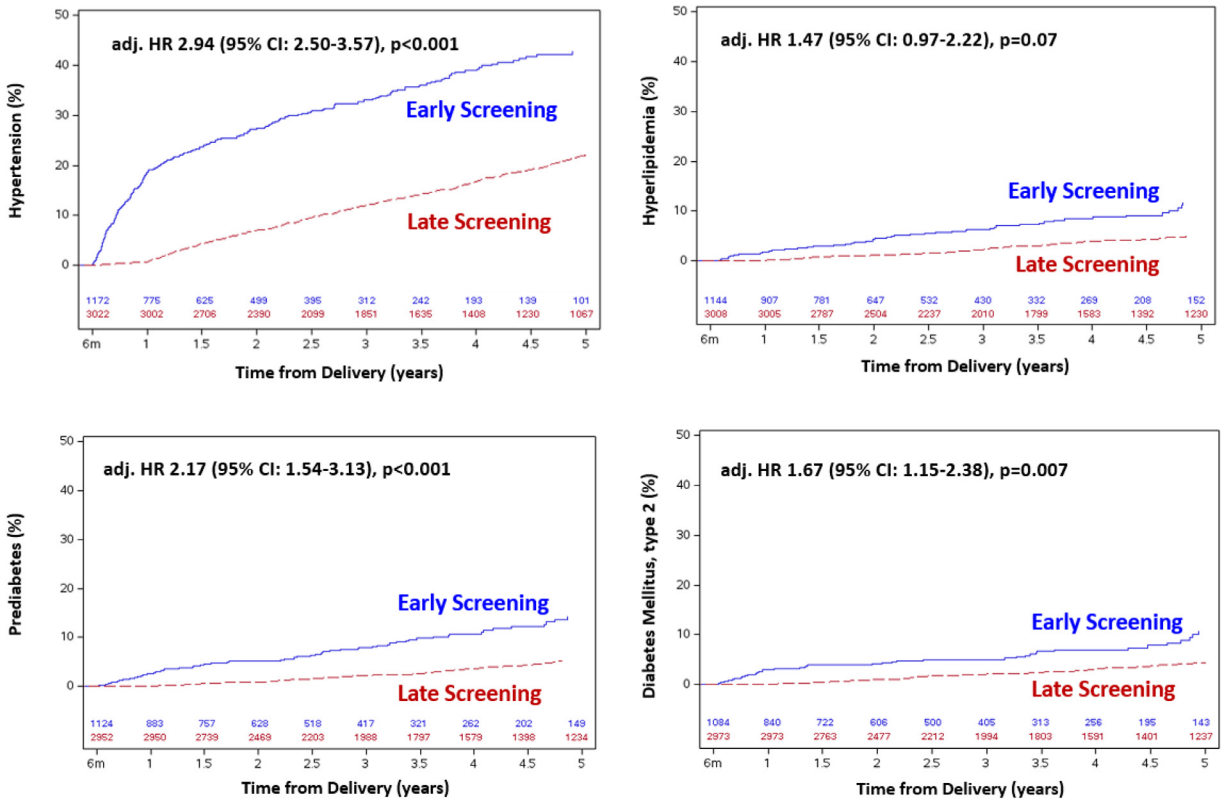


mary care, ob-gyn, and cardiology is likely to improve transitions of care at a vulnerable time after a pregnancy complicated by HDP and can provide the early preventive CV management recommended for women with HDP.[26]

This study found that nearly a quarter of women with HDP had at least 1 new CV risk factor detected within 5 years of delivery. Although it is often thought that there is a considerable time interval between HDP and the development of CV disease, our work confirms earlier studies that have shown CV risk can present in the immediate postpartum years. Veerbeek et al. found that essential HTN developed within 5 years of delivery among 25%-45% of women with HDP.[27] In a Denmark cohort, a third of women with HDP developed HTN in the following decade, with women of more advanced age demonstrating the highest risk.[28] Similarly, we found that HTN was the most common CV risk factor identified within 5 years of delivery with a cumulative incidence of 26%. Our findings also align with results from the Nulliparous Pregnancy Outcomes Study Monitoring Mothers-to-be Heart Health Study (nuMoM2b), a prospective observational cohort study in the U.S. that found a 2.7-fold increase in risk for incident HTN within 2 to 7 years after a first pregnancy complicated by HDP.[29] Furthermore, a recent study of women with HDP that underwent peripartum echocardiography demonstrated that increased left ventricular mass, relative wall thickness, and an elevated E/e' ratio during pregnancy were indicators of persistently elevated postpartum BP.[30] Thus, peripartum cardiac imaging may further risk stratify those at greatest risk for postpartum HTN.

Our study also found that incident HLD, prediabetes, and DM2 were also frequently detected postpartum, particularly among those screened early. This is the first study, to our knowledge, to report the incidence of prediabetes after a HDP, which was newly diagnosed in almost 7% of women. These findings confirm that the hy-

Figure 5. Cumulative incidence of individual cardiovascular risk factors by screening group. The incidence of hypertension (upper left), hyperlipidemia (upper right), prediabetes (lower left) and diabetes mellitus, type 2 (lower right) between early and late screening groups among women with HDP.



pertensive disorders of pregnancy are an early marker of subclinical CV risk. This risk must be recognized by providers caring for women with HDP in order to intervene with early preventative strategies that decrease the incidence of CV risk factors and potentially mitigate the development of CV disease later in life.

This study highlights the importance of closely monitoring women with HDP for the development of CV risk factors in the years after delivery. However, this CV monitoring is required at a time in women's lives when their attention to their own health may be de-prioritized or rivaled by caring for infants, young children, and potentially, aging parents.[31,32] Future work should focus on implementation of practice-based systems to ensure that these women get close BP monitoring and the effective risk factor modification needed to decrease the burden of CV disease later in life. These interventions should be designed to provide equitable access to timely screening and optimal management for all women because our findings suggest that certain populations (e.g. Hispanic ethnicity and those with government insurance) may have differential access to optimal screening. Early preventive care that is scheduled before discharge in women with HDP or aligned with pediatrician visits could ultimately improve CV health in women. Recent studies demonstrating the success of home BP monitoring and physician-guided self-management of anti-hypertensive medications in the postpartum period among women with HDP underscores the importance of engaging and empowering high-risk women with HDP to be active participants in optimizing their cardiovascular health.[33]

Limitations

This was a retrospective study and the indication for BP measurement, specifically if performed as part of routine care or explicitly for BP screening, is unknown. A causative association between early BP screening and an increase in the detection of CV risk factors cannot be established due to the retrospective study design. Likewise, a causal relationship between guideline publication and/or EHR implementation and the increase in early BP screening cannot be determined. Patients were excluded if they had no follow-up postpartum in either healthcare system (and therefore no BP measurement) or only 1 follow-up before 6 months (before the recommended screening period) and no subsequent follow-up. There-

fore, data to assess for the presence and timing of screening in these women was lacking. Since it is unknown if they received care in another healthcare system or if they had no clinical follow-up, rates of screening may be underestimated and these exclusions may limit the generalizability of these findings. Despite this limitation however, this was a diverse cohort with respect to race (32% Black), ethnicity (14% Hispanic), preexisting conditions, and insurance coverage. Future prospective studies of longer duration are needed to assess the impact of early screening and risk factor modification on CV disease prevention in this high-risk population of women.

Conclusions

Early postpartum BP screening was performed in a minority of women with HDP, but resulted in greater detection of CV risk factors. Almost 1 in 4 women with HDP had at least 1 new CV risk factor detected within 5 years of delivery. A multidisciplinary approach and implementation of practice-based systems may improve transitions of care after a pregnancy complicated by HDP. More intensive postpartum CV screening and targeted interventions are needed to optimize CV health in this high-risk population of women with HDP.

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Conflict of interest

None of the authors have any conflicts of interest.

CRediT authorship contribution statement

Melissa A. Daubert: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Amanda Stebbins:** Formal analysis, Writing – review & editing. **Rachel Peragallo-Urrutia:** Funding acquisition, Investigation, Methodology, Writing – review & editing. **Karen Chiswell:** Formal analysis, Supervision, Validation, Visualization, Writing – review & editing. **Matthew S. Loop:** Methodology, Writing – review & editing. **Ceshae Harding:** Writing – review & editing. **Thomas Price:** Conceptualization, Investigation, Writing – review & editing. **Tracy Y. Wang:** Conceptualization, Investigation, Methodology, Supervision, Writing – review & editing.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ahj.2024.03.014.

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