JACC: ADVANCES VOL. 3, NO. 3, 2024

STATE-OF-THE-ART REVIEW

Hypertensive Disorders of Pregnancy

Innovative Management Strategies

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ABSTRACT

Hypertensive disorders of pregnancy (HDP) complicate 13% to 15% of pregnancies in the United States. Historically marginalized communities are at increased risk, with preeclampsia and eclampsia being the leading cause of death in this population. Pregnant individuals with HDP require more frequent and intensive monitoring throughout the antepartum period outside of routine standard of care prenatal visits. Additionally, acute rises in blood pressure often occur 3 to 6 days postpartum and are challenging to identify and treat, as most postpartum individuals are usually scheduled for their first visit 6 weeks after delivery. Thus, a multifaceted approach is necessary to improve recognition and treatment of HDP throughout the peripartum course. There are limited studies investigating interventions for the management of HDP, especially within the United States, where maternal mortality is rising, and in higher-risk groups. We review the state of current management of HDP and innovative strategies such as blood pressure self-monitoring, telemedicine, and community health worker intervention. (JACC Adv 2024;3:100864) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

EPIDEMIOLOGY OF HYPERTENSIVE DISORDERS OF PREGNANCY

Hypertensive disorders of pregnancy (HDP), defined as preeclampsia or eclampsia, gestational hypertension, and chronic hypertension, complicate 13% to 15% of all pregnancies in the United States (**Table 1**).[1] Physicians and health care providers must be vigilant for the diagnosis across specialties. Criteria for diagnosis of hypertension in pregnancy include 2 readings of a systolic blood pressure (BP) ≥140 mm Hg and/or a diastolic BP ≥90 mm Hg, taken over a period of 4 to 6 hours. Preeclampsia, defined as an acute rise in BP and proteinuria (≥300 min/24 h or ≥1+ with dipstick) after the 20th week of pregnancy or postpartum, affects approximately 2 to 8% of pregnant women.[2] Preeclampsia with severe features includes one or more of the following: a BP ≥160/110 mm Hg, proteinuria (2.0 g/24 h or ≥2+ dipstick), new-onset serum creatinine >1.2 mg/dL, platelets <100,000/mm^3,

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Gabriele Egidy Assenza, MD, served as the Guest Editor for this paper. Michael Landzberg, MD, served as Guest Editor-in-Chief for this paper.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

Manuscript received June 8, 2023; revised manuscript received November 27, 2023, accepted January 4, 2024.

ISSN 2772-963X https://doi.org/10.1016/j.jacadv.2024.100864

ABBREVIATIONS AND ACRONYMS

BP = blood pressure

HDP = hypertensive disorders of pregnancy

increased lactate dehydrogenase, elevated alanine aminotransferase or aspartate aminotransferase, or persistent headache or other cerebral or visual disturbance and persistent epigastric pain. Preeclampsia can progress to eclampsia, additionally defined by new-onset seizures during or after labor.[3] Gestational hypertension is diagnosed as hypertension diagnosed for the first time during pregnancy that returns to normal <12 weeks postpartum and without proteinuria or diagnostic features of preeclampsia.[4] Chronic hypertension is persistence of elevated BP ≥12 weeks postpartum or hypertension in pregnancy that was also present prior to 20 weeks' gestation.[4] Together, HDP accounts for 7% of maternal deaths in the United States.[5] The incidence of preeclampsia has increased over recent decades, surpassing the rate of diseases like Alzheimer's, obesity, diabetes, and chronic kidney disease.[6,7] The incidence of HDP has exponentially increased from 528.9 per 10,000 deliveries in 1993 to 912.4 per 10,000 deliveries in 2014.[8] Risk factors for preeclampsia include age, with a higher incidence among those ages <25 and >35 years, diabetes, obesity, and preexisting cardiovascular disease (CVD).[7] Additionally, dietary intake of sodium has been found to increase risk for HDP, with those consuming >3.5 g/d having a 54% higher risk for chronic hypertension and a 20% higher risk for preeclampsia compared to those consuming <2.8 g/d.[8]

HDP is prevalent and undertreated in pregnant individuals from historically marginalized communities due to systemic barriers to health care. There is increased risk for preeclampsia among minority groups, with higher frequency of preeclampsia among non-Hispanic Black women compared to non-Hispanic White women (16.7% vs 13.4%, respectively).[8,9] Maternal mortality is approximately 3-fold higher in Black individuals, with preeclampsia and eclampsia leading causes of death, accounting for 30% of pregnancy-related deaths.[9] A single-center prospective study that screened >10,000 postpartum women detected a new diagnosis of postpartum hypertension in 8%, most frequently in Black individuals with higher body mass index.[10] Short-term adverse outcomes resulting from preeclampsia include increased risk for cesarean delivery, placental abruption, prolonged maternal hospital stay, and increased mortality. Those who develop preeclampsia prior to 37 weeks have an 8-fold increase in adverse pregnancy outcomes like preterm birth and placental abruption.[7] Additionally, hypertension is the foremost indication for postpartum readmission.[11]

Long-term adverse outcomes due to HDP are well documented. Pregnant individuals with HDP have approximately double the risk of ischemic heart disease in the first 12 years after pregnancy compared to those who are normotensive.[12] There may be a significant relationship between the timing of onset of

HIGHLIGHTS

- HDP complicate 13 to 15% of all pregnancies in the United States.
- Individuals with HDP require more frequent and intensive peripartum management than routine standard of care.
- Innovative management strategies are needed, but the best approach, timing, frequency, and intensity are uncertain.
- Blood pressure self-monitoring, telemedicine, and community health worker intervention may be novel approaches to HDP.

TABLE 1 Definitions of Hypertensive Disorders of Pregnancy

Chronic HTN	SBP ≥140 mm Hg or DBP ≥90 mm Hg on at least 2 occasions 4 h apart at a gestational age of <20 wk
Gestational HTN	SBP ≥140 mm Hg or DBP ≥90 mm Hg on at least 2 occasions 4 h apart at a gestational age of >20 wk with no features of preeclampsia
Preeclampsia	Without severe features: SBP ≥140 mm Hg or DBP ≥90 mm Hg on at least 2 occasions 4 h apart at a gestational age of >20 wk with proteinuria (>300 mg on 24-h urine protein collection or 0.3 mg on urine point of care)
	With severe features: SBP ≥140 mm Hg or DBP ≥90 mm Hg on at least 2 occasions 4 h apart at a gestational age of >20 wk with proteinuria and evidence of end organ injury SBP ≥160 mm Hg or DBP ≥110 mm Hg on at least 2 occasions 4 h apart OR persistent severe hypertension requiring IV antihypertensives for control to bring SBP <160 mm Hg or DBP <110 mm Hg
Eclampsia	Preeclampsia + seizures

DBP = diastolic blood pressure; HTN = hypertension; SBP = systolic blood pressure.

preeclampsia and long-term cardiovascular outcomes. Individuals who develop preeclampsia after 37 weeks have a 2-fold increase in long-term adverse cardiovascular outcomes.[7] There are data demonstrating an association of advanced maternal age (35-44 years) and very advanced maternal age (>45 years) on HDP risk itself, though whether that translates to increased risk of major cardiovascular events in older women is not well established.[13] Individuals with HDP have a higher risk of developing stroke compared to those who do not have HDP (34.5% vs 6.9%), and the risk of stroke is higher among non-Hispanic Black and Hispanic/Latina women as compared to non-Hispanic White women.[8] Preeclampsia is also associated with adverse long-term kidney outcomes, including an increased risk of developing glomerular or proteinuric kidney disease and end-stage kidney disease within 5 to 10 years after pregnancy.[14] The risk is higher in women with multiple preeclamptic pregnancies or previous preterm preeclampsia.

Late-onset preeclampsia can present in individuals with or without history of antepartum HDP. Acute BP elevation is frequently observed 3 to 6 days postpartum. Thus, the standard of care postpartum visit at 6 weeks after delivery fails individuals with preeclampsia occurring in the first few days postpartum. Most readmissions for acute hypertension occur within 10 to 20 days of discharge, well before the usual postpartum visit.[15] From the American College of Obstetricians and Gynecologists recommendations, "blood pressure evaluation is recommended for women with hypertensive disorders of pregnancy no later than 7 to 10 days postpartum, and women with severe hypertension should be seen within 72 hours; other experts have recommended follow-up at 3 to 5 days".[16] Prioritizing those with the highest BPs and more severe features for postpartum BP checks or visits by 3 days appears reasonable.

Individuals without a previous diagnosis of hypertension are at particularly increased risk for severe maternal morbidity from acute BP elevation compared to those with chronic hypertension. Over half of all maternal deaths occur in the postpartum period.[17] Causes of death from HDP include systolic heart failure, cerebrovascular disease, myocardial infarction, and cardiac arrest.[18] In the context of HELLP syndrome (hemolysis, elevated liver enzymes, and low platelets), additional causes of HDP-related death are placental abruption, acute respiratory distress syndrome, disseminated intravascular coagulation, hepatic hemorrhage, hypoxic ischemic encephalopathy, and acute kidney injury.[19] Among HDP-related deaths, 44.3% of deaths occurred on day 1 and 37.1% of deaths on days 2 to 7.[20] In a review of 232 pregnancy-related deaths evaluated by 13 state Maternal Mortality Review Committees, approximately 60% of postpartum maternal deaths were determined to be preventable.[21] Prevention of mortality likely requires a multipronged approach from highly responsive health systems, such as patient education on BP, healthy diet/lifestyle, medical therapy (aspirin, antihypertensives, magnesium), surveillance for proteinuria and elevated BP, use of safety bundles, strategically timed delivery, and provider action to treat emergent symptoms.[22,23] The immediate postpartum period, commonly termed the "fourth trimester," is a prime window of opportunity for intervention and transition to primary or cardiovascular care. Short-term management of HDP immediately postpartum may influence long-term BP control, although data is limited in this regard.[24]

PATHOPHYSIOLOGY OF HYPERTENSIVE DISORDERS OF PREGNANCY

The pathophysiology of HDP is not well understood. Hypertension in pregnancy is thought to be due to a combination of improper trophoblast differentiation and abnormal regulation of cytokines, adhesion molecules, major histocompatibility complex molecules, and metalloproteinases, which lead to abnormal differentiation of spiral arteries and subsequent placental hypoperfusion and ischemia.[25] Antiangiogenic factors that are released also play a role in the development of systemic hypertension due to systemic endothelial dysfunction.[25] Current research includes several hypotheses as to how preeclampsia can occur, including contact between the maternal immune system and the placental semiallogeneic trophoblast, chronic uteroplacental ischemia, oxidative stress, immune maladaptation, imbalance of angiogenic factors, genetic imprinting, altered renal hemodynamics with impaired renin angiotensin signaling, an exaggerated maternal inflammatory response, and vascular endothelial dysfunction.[26]

Angiogenic factors play a key role in regulation of placental vascular differentiation; thus, there may be an imbalance between angiogenic factors in the pathogenesis of preeclampsia.[27] In early gestation of normal pregnancy, proangiogenic factors like endoglin (Eng), placental growth factor (PlGF), fms-like tyrosine kinase-1(Flt1), and vascular endothelial growth factor are highly expressed by invasive trophoblasts. However, decreased expression of these factors can lead to the inadequate cytotrophoblastic invasion seen in preeclampsia. The splice variants of

Flt1 and Eng, namely soluble Flt1 (sFlt1) and soluble Eng (sEng), serve as ligand traps by binding to angiogenic factors. In normal pregnancy, sFlt-1 blood levels remain low in early pregnancy and increase toward the third trimester to allow for cytotrophoblastic invasion during early pregnancy. However, elevated levels of sFlt1 in pregnancy, as seen in preeclampsia, can lead to defective cytotrophoblast invasion and high plasma sFlt1:PlGF ratios, reflecting severe disease and associated with adverse clinical outcomes. Levels of sFLT-1 can persist early postpartum and lead to preeclampsia usually within 48 hours to 6 weeks postpartum. Interestingly, postpartum preeclampsia has also been associated with epigenetic modifications, with CpG methylation sites as markers for identification of postpartum preeclampsia.[27,28]

CURRENT MANAGEMENT OF HYPERTENSIVE DISORDERS OF PREGNANCY

Preventing HDP altogether is most optimal to avoid adverse outcomes. There appears to be an inverse relationship between physical activity, gestational hypertension, and preeclampsia.[29] Preventative medical management with aspirin is recommended per American College of Obstetrics and Gynecology (ACOG) guidelines for those at increased risk for preeclampsia, including those with previous preeclampsia, multifetal gestation, chronic kidney disease, autoimmune disease, type 1 or type 2 diabetes mellitus, and chronic hypertension.[30] For these individuals, there is a Level of Evidence: A recommendation to start low-dose aspirin (81 mg) before 16 weeks of gestation for prevention of preeclampsia. Individuals who develop preeclampsia after 37 weeks of gestation are recommended to undergo immediate delivery.[22,30]

Severe hypertension and preeclampsia must be treated early on to prevent adverse outcomes. The BP target for acute severe hypertension and preeclampsia ante or postpartum is a BP of 140-150/90-100 mm Hg.[31] The optimal BP target for the treatment of mild chronic hypertension is an area of active investigation. In an open-label, multicenter, randomized controlled trial (RCT) assigning pregnant women with mild chronic hypertension (BP <160/100 mm Hg) to antihypertensive medication, a BP target of 140/90 mm Hg in patients with chronic hypertension was associated with lower risk of developing preeclampsia with severe features, medically indicated preterm birth (<35 weeks of gestation), placental abruption, or fetal or neonatal death, and there was no increase in the risk for small-for-gestational-age birth weight.[32] Medical therapies for HDP antepartum include hydralazine, labetalol, nifedipine, and methyldopa. Postpartum, the angiotensin-converting enzyme inhibitor, enalapril, may be useful and is compatible with breastfeeding in normal-term neonates.[33] Magnesium is used for seizure prophylaxis and diuretics for edema or volume overload postpartum.

The routine use of diuretics is unclear in preeclampsia.[34] Valensise et al[35] assessed pregnant individuals with uterine artery Doppler to evaluate placental arterial waveforms and maternal transthoracic echocardiography, calculating stroke volume and peripheral vascular resistances. At a hemodynamic level, there appeared to be 2 phenotypes of preeclampsia: 1) early onset (<34 weeks), characterized by low cardiac output, high resistance, and depleted intravascular volume, a phenotype more commonly associated with bilateral notching of the uterine artery Doppler, fetal growth restriction, and worse maternal and perinatal outcomes; and 2) late onset (≥34 weeks), characterized by high cardiac output, reduced resistance, and increased intravascular volume, a phenotype more commonly associated with obesity, normal fetal growth, and more favorable maternal and perinatal outcomes. Understanding different preeclampsia phenotypes could modify the choice of therapy, specifically the use of diuretics.

Following delivery, fluid that has been sequestered in the extravascular space is mobilized, producing a large auto-infusion of fluid from the extravascular to the intravascular compartment. Trials in antepartum patients have shown insufficient evidence to draw reliable conclusions about diuresis, possibly because these could have also included the phenotype associated with intravascular depletion.[35,36] Several studies have demonstrated that diuretics may be useful in postpartum women with HDP, possibly including more individuals with a phenotype of increased intravascular volume. Small trials of individuals with severe preeclamptic features postpartum have shown decreased requirement for additional antihypertensives if a combination of furosemide and nifedipine was used.[37] Patients with preeclampsia with severe features randomized to treatment with 20 mg daily furosemide were found to have significantly lower BP by postpartum day 2 and required significantly less antihypertensive therapy on discharge compared to those treated with placebo.[38] Another study evaluating patients with gestational hypertension and preeclampsia with and without severe features demonstrated that patients randomized to furosemide 20 mg daily for the first 5 days postpartum were less likely to have persistent

hypertension at postpartum day 7.[39] Additional research is needed to validate different preeclampsia phenotypes and the best therapy.

Given that preeclampsia can develop de novo after delivery, women in the postpartum period should be given discharge instructions that include information about the signs and symptoms of preeclampsia as well as the importance of presenting for medical evaluation in the event that they occur.[16] As delineated by the ACOG guidelines, treatment with first-line agents in patients with acute severe hypertension, identified as systolic BP ≥160 mm Hg or diastolic BP ≥110 mm Hg, should be initiated within 30 to 60 minutes to reduce risk of maternal stroke. First-line agents for treatment in both pregnancy and postpartum include IV labetalol and hydralazine, or more recently, the use of oral nifedipine if IV access is not established. BP targets in cases of severe hypertension should not aim for normalization of BP but rather target a range of 140 to 150/90 to 100 mm Hg. In severe cases, such as when medication fails to reduce BP to the target range, consultation with anesthesiologist, maternal fetal medicine subspecialist, or critical care subspecialist is recommended.[31]

ACOG and the Royal College of Obstetricians and Gynecologists recommend achieving a BP of 140/90 mm Hg in the immediate postpartum period.[40,41] However, there are no standardized management guidelines for specific antihypertensive agents or parameters for medication uptitration in the postpartum period. Thus, physician preference and experience, as well as safety of medical therapy during breastfeeding often affect the approach.[42]

INNOVATIVE MANAGEMENT OF HYPERTENSIVE DISORDERS OF PREGNANCY

BLOOD PRESSURE SELF-MONITORING AS A STRATEGY FOR TREATMENT OF HYPERTENSIVE DISORDERS OF PREGNANCY. Self-monitoring with a health system-provided BP cuff, when combined with outreach to patients by medical personnel for antihypertensive management, appears to be a viable strategy for antepartum BP control (**Table 2**). Two well-powered RCTs, BUMP1 and BUMP2, did not find differences between those randomized to self-monitoring of BP vs usual care.[43,44] However, those trials did not include automated transfer of BP readings to physicians via the electronic medical record (EMR) or outreach by the medical team; instead, they relied on the volunteer to contact the medical team for elevated BP readings. An observational study studying universal screening noted lack of participation in self-monitoring unless a BP cuff was provided.[10] By comparison, SNAP-HT demonstrated feasibility and improved diastolic BP in the intervention group at 6 months with a 7 mm Hg decrease in long-term BP using self-management of postpartum hypertension with daily home BP monitoring and automated self-controlled medication adjustment via telehealth.[45] High volunteer satisfaction was noted in 4 studies: a qualitative analysis of the BUMP2 study, Heart Safe Motherhood, a University of Wisconsin study, and Safe@Home.[44,46-48] In these studies, there were frequent reminders and contact with the study teams. In BUMP2, volunteers highlighted interactions with clinicians, structured follow-up, and individualized support as aspects that they preferred and were motivated to reduce HDP in future pregnancies. There were significant health knowledge gaps despite college-level education, pointing to the importance of universal education on HDP.[44] In the University of Wisconsin study of postpartum management, where telehealth was used for communication, there was a 95% retention rate and high patient satisfaction, and investigators also identified 16% of their cohort with uncontrolled BP.[47] The Safe@Home study using telemonitoring to monitor BP, admissions for suspected preeclampsia and hypertension were lower in those with telemonitoring compared to those without, in addition to high levels of satisfaction in the telemonitoring group.[48] Additionally, an observational study investigating self vs ambulatory BP monitoring, found that patients were more comfortable with self-monitoring, citing less anxiety and discomfort.[49] Furthermore, a University of Pittsburgh observational study found that when patients were given educational materials on discharge, with follow-up at 1-week intervals, studying universal screening noted lack of participation in self-monitoring; in those who did participate, 8% of the cohort was diagnosed with potential new-onset hypertension and 0.7% were diagnosed with severe hypertension.[10] Interestingly, a meta-analysis of home monitoring showed no significant differences between those as compared to usual care with respect to postpartum readmission and BP monitoring acutely after discharge, possibly due to clinical heterogeneity and low quality of evidence.[50] While more RCT data are needed, a multilevel intervention with patient-provider interaction appears more effective in achieving the goal of BP reduction than self-monitoring in isolation.

TELEMEDICINE FOR HYPERTENSIVE DISORDERS OF PREGNANCY. Greater than 40% of women do not attend a recommended postpartum visit by 6 weeks; thus, it is important to study the utilization of

TABLE 2 Rigor and Reproducibility of Randomized Controlled Trials and Observational Studies of Blood Pressure Monitoring in Peripartum Cohorts

First Author, Study	Sample	Design	Intervention	Follow-up Time	Key Findings
Tucker et al,[43] BUMP 1	Antepartum, England, >70% White	RCT N = 2,441	Self-monitoring, telemonitoring, prompt to contact clinic for high BP	Until Delivery	No change in time to first clinic recording of HTN by provider
Chappell et al,[44] BUMP2	Antepartum, England, >49% White	RCT N = 850	Self-monitoring, telemonitoring, prompt to contact clinic for high BP	Until Delivery	No change in mean SBP
Cairns et al,[45] SNAP-HT	Postpartum, England, >80% White	RCT N = 91	Self-monitoring, automated medication adjustment via telemonitoring + home visits	6 mo	90% completion SBP and DBP lower in intervention group most markedly at 6 wk, DBP lower at 6 mo
Janssen et al,[46] Heart Safe Motherhood	Postpartum, U.S. ~42% White, 34% Black, 12% Hispanic/Latina	Observational N = 199	Text based informing of BP, physician-directed therapy or admission	Postpartum day 10	97% of participants submitted 1 BP
Hoppe KK et al [47]	Postpartum, U.S. 93% White, 9.1% Hispanic/Latina	Prospective single cohort study N = 55	Telehealth intervention for BP monitoring	6 wk postpartum	Retention rate 95%, incidence of severe HTN was 16%, 53% of participants required treatment, no readmissions, 86% of participants satisfied
Van den Heuvel et al,[48] Safe@Home	Antepartum, the Netherlands, >75% White	Case-control N = 236	Self-monitoring, provider acting on automated results	16 wk gestational age continued until delivery	Less antenatal visits and admission in intervention group, high satisfaction
Hacker et al[10]	Postpartum, U.S. >67% non-Hispanic White	Prospective observational N = 1,192	Given educational materials on discharge, follow-up with nurse at 1-wk intervals	NA	26% could not participate because they did not have BP cuff. Of the remainder participating, 8% had a potential new diagnosis of a hypertensive disorder of pregnancy, and 0.7% having severe hypertension
Taylor et al[49]	Antepartum and postpartum, Auckland New Zealand	Observational N = 113	Given self BP cuff or ambulatory cuff (24-h monitor)	24 h	Most participants preferred self BP checks, citing ambulatory cuff caused more anxiety, discomfort

DBP = diastolic blood pressure; ED = emergency department; HTN = hypertension; NA = not available; RCT = randomized controlled trial; SBP = systolic blood pressure; SPEC = severe preeclampsia.

telehealth and telemedicine to aid in attendance of these visits.[16] Telemedicine is a viable alternative with greater attendance to postpartum visits in several studies (**Table 3**). A single center study in a U.S. urban minority community indicated women who did not attend an in-person office visit were more often Black (87% vs 56%), $P < 0.01$) and younger (29.1 vs 31.4 years, $P = 0.04$), but no disparity by race or ethnicity was seen for telehealth visits.[51] Attendance for a telehealth visit was high, 70% vs 32% for an in-person visit.[51] Telephone, text message, and video conference-based communication were well received by patients and providers in several studies.[52,53] However, a University of Arkansas study of self-monitoring in a rural cohort using mobile health (mHealth) wireless transmitting equipment found several challenges with this strategy.[52] Those using the application found it easy to use, while nonusers were concerned about incorporating it into their daily routine as new parents. Barriers to using mHealth included concern for wireless transmission in rural areas, single BP cuff size availability, and stress associated with monitoring of BP. Most telehealth or mobile health studies with BP cuff prototypes have been tested in small studies and lack integration with EMRs or broader medical practice.[54] The "OB Nest" program at Mayo Clinic is an antepartum model involving self-monitoring, texting, and an online peer support community.[53] The program has reduced in-person prenatal care, decreasing health care costs, with similar delivery outcomes. Participants in the program reported feeling more

TABLE 3 Rigor and Reproducibility of Previous Studies of Telemedicine in Peripartum Cohorts

First Author, Study	Sample	Design	Intervention	Follow-Up Time	Key Findings
Sanghavi et al[51]	Postpartum, U.S., >73% Black	Retrospective cohort N = 119	Telemedicine and in-person	NA	70% completion for telemedicine vs 32% for in-person, those who were more likely to not complete an in-person visit were more likely to be Black (87% vs 56%) and younger (29.1 vs 31.4); this difference not seen with telemedicine
Payakachat et al,[52] mHealth	Postpartum, U.S., >48% White	Prospective cohort N = 37	Self-monitoring of BP, weight, pulse, O_2 sat, and symptom survey with wireless transmission to providers	NA	Users had higher facilitating condition scores, higher levels of perceived benefits, and lower levels of perceived barriers vs nonusers, increased admission in users
De Mooji et al,[53] OB Nest	Antepartum (<5 mo gestation), U.S., 85% White	Observational study N = 20	Self-monitoring tools, online communities, and text-based communication	Antepartum to 6 wk postpartum	Improved patient satisfaction, lower anxiety levels, lower health care costs, no difference in delivery outcomes
Hirshberg et al[55,56]	Postpartum, U.S., >66% Black	RCT N = 206	Self-monitoring of BP with text messaging platform	3 wk after delivery	Increase in at least 1 BP measurement in the first 10 d postpartum in the texting; greater attendance (>90%) to postpartum visits vs usual care among Black patients
Khosla et al[57]	Postpartum, U.S., >74% non-Hispanic Black	Retrospective cohort N = 473	Telehealth visits during the COVID pandemic to replace in person standard postpartum visit.	6 wk after delivery	Increased attendance of follow-up appointment in telehealth group vs in person, especially in Black individuals; Race-ethnic gap in care eliminated using telehealth
Rossiter et al[58], BP2	Postpartum, Australia, >64% White	RCT N = 157, N = 34 interviewed	Three arms: 1) usual care; 2) brief education intervention; 3) extended lifestyle intervention, 1 and 2 + phone based service, dieticians, exercise physiologists	12 mo postpregnancy	Extended lifestyle intervention increased recognition of their cardiac health risk, with greater motivation to make lifestyle and behavioral changes
Rich-Edwards et al,[59] Heart Health 4 Moms (HH4H)	Postpartum, U.S., mostly White	RCT N = 151	Online educational modules, community forum and peer coaching vs control (internet links alone)	9 mo	Intervention participants reported significantly greater knowledge of cardiovascular risk factors, healthy eating, more physical activity vs controls
Herring et al[60]	Postpartum, U.S., 100% Black or Hispanic/Latina	RCT N = 22	Peer coach by phone, in-person, social media interaction	14 wk after delivery	Increased weight loss among intervention vs usual care

NA = Not applicable; BP = blood pressure; RCT = randomized controlled trial.

connected with providers, less anxious, and more knowledgeable.[53] A randomized control trial at the University of Pennsylvania used texting to communicate postpartum BP.[55] Their study found that the texting group was more likely to identify BP spikes than those presenting to office visits alone in the first 10 days postpartum, a high-risk period.[55]

Use of telehealth may also reduce racial disparities.[51,56,57] In a study at the University of Pennsylvania, Hirshberg et al[56] found decreased racial disparity when using a text-messaging-based platform. Their study found that over 90% of Black participants provided a BP measurement compared to the 33% who presented for an in-person BP visit as

per routine care. The implementation of telehealth with audio-based visits in a study done by Khosla et al[57] found significant improvement in adherence with at least 1 visit for follow-up for hypertension in the postpartum period among Black patients (48.5%-76.3%, $P < 0.001$).

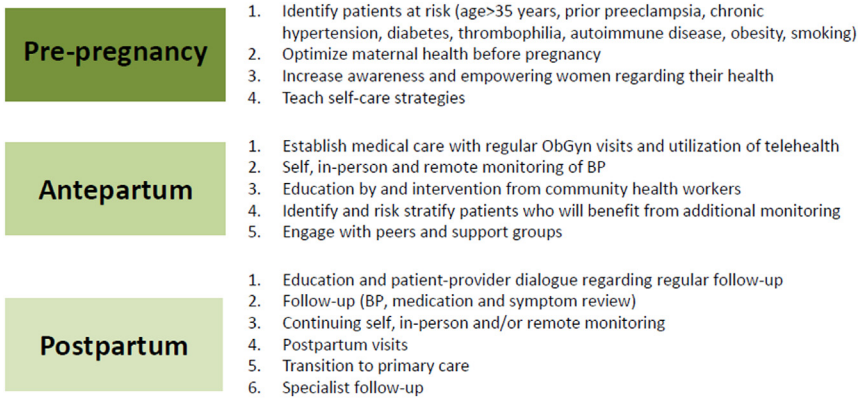
Lifestyle interventions have been conducted via televisits. In a subset of the BP2 trial, women were more likely to adopt healthy habits if provided with an intense intervention with in-person consultation with a provider and dietitian followed by 6 months of telephone-based coaching.[58] Participants cited high accountability, increased education about healthy habits, and more motivation toward making lifestyle changes along with increased perceived risks of their cardiovascular health postpregnancy.[58] In the HH4H (Heart Health 4 Moms) study, a total of 150 women were enrolled in an RCT to reduce CVD risk through an online intervention vs self-directed care in controls.[59] The HH4H group improved CVD risk knowledge, self-efficacy to achieve a healthy diet, and reduced physical inactivity. This study enrolled mostly White, higher-income, and college-educated women who were normotensive at baseline.[59] A small RCT in urban minority centers (Philadelphia Women, Infants, and Children program) found the use of texting BP measurements to providers and peer coaching to improve the frequency of BP measurement and weight loss.[60] Though data from rigorous RCTs are limited, telehealth may improve patient-provider communication, overcome caregiving and logistical barriers to in-person visits, and extend medical care into the home.

COMMUNITY HEALTH WORKERS FOR PATIENT SUPPORT AND EDUCATION IN HYPERTENSIVE DISORDERS OF PREGNANCY. The philosophy behind community health work is to recruit and train individuals with shared lived experiences to provide supportive care to patients either in the community or within health systems. Therefore, community health workers (CHWs) often have congruent cultural and language identities with the community they serve. CHWs provide peer support and linkage to health care and social services, extending the care team into homes across a region. They often provide practical information about exercise, diet, smoking cessation, and stress reduction, present information in layperson's terms, and their work may help in building a trusting relationship between the health system and community. Training is variable, with some programs offering core curricula and certifications. CHWs have most often been deployed in low- and middle-income countries or other resource-limited environments, but the Centers for Disease Control and American Public Health Association endorse the use of CHWs in chronic disease management, antiretroviral therapy for HIV, cancer screening, and asthma control.[61]

Few studies have focused on CHWs role in maternal health. The largest, the CLIP RCTs, deployed CHWs throughout India, Pakistan, and Mozambique for antepartum treatment of preeclampsia. The study was principally focused on the association of BP control with neonatal outcomes.[62] CHWs were deployed to homes and used a digital phone-based application for patient assessment, measured BP, administered a dipstick urinalysis, gave patients oral and intramuscular medications, and referred patients for further care. The study found that CHWs were adequately utilized and that worsened BP control was associated with worse neonatal outcomes than for women with a normal BP but did not focus specifically on maternal health outcomes.[63] The antepartum Health Start cohort in Arizona was a retrospective, propensity score-matched study of antepartum care in which patients were assigned a CHW. Involvement of a CHW increased prenatal care attendance significantly in a historically marginalized community of Latina and Native American individuals and mostly publicly insured cohort.[64] Though not a pregnancy-related study, CHW and telehealth were combined in the DREAM-GLOBAL study.[65] A Canadian Indigenous and Tanzanian sample of middle-aged men and women involved a CHW to help volunteers measure BP on a centrally located device in a community health center, where they submitted measurements to a central server. Participants felt better educated on BP and lifestyle changes and perceived improved communication with physicians and support from site visits. CHW and health care providers found improved communication with participants and between each other.

CHWs have improved outcomes for individuals living with cardiovascular conditions (heart disease, stroke, type II diabetes), asthma, and cancer. A systemic review (including 16 RCTs but excluding maternal health) indicated a statistically significant reduction in emergency department (23%-51%), urgent care visits (60%), and hospitalization (21%-50%) when CHWs were integrated into the inpatient care team.[66] Combining CHWs with other strategies may be effective to reduce health care utilization but requires further investigation, particularly for antepartum or postpartum care. There are limited RCTs

FIGURE 1 **Integrating Innovative Management Strategies for Hypertensive Disorders of Pregnancy in Patient Care Across the Prepregnancy, Antepartum, and Postpartum Periods**



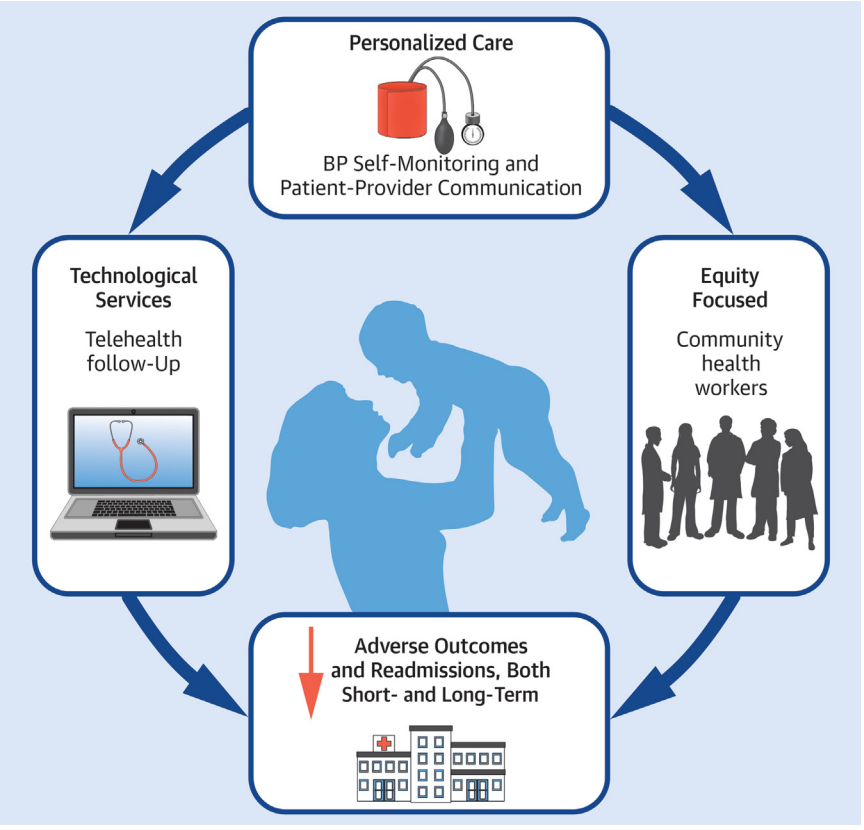
BP = blood pressure.

focused on cost and utilization with variability in the magnitude of the effect, likely due to differences in study design, and evidence is insufficient to draw conclusions about the effects of CHWs on chronic disease management.[67] A systematic review encompassing 8 studies (n = 6,500) found that 7 studies found no impact on mental health quality of life or mental health outcomes; 2 studies in the United States found improved quality of care in those with multiple-morbidity conditions and reduced hospitalizations.[68] However, these studies have low certainty of evidence due to risk of bias, inconsistency, and imprecision, thus pointing to a need for future studies investigating the role of CHWs in these conditions.[68] Important considerations for future studies of CHW include: tailored scope of work, training, mentorship, supervision, ratio of CHW to patient, and financing. The National Academies of Sciences, Engineering, and Medicine 2019 report provides health systems with guidance on how social care integration may promote improved health outcomes.[69]

INNOVATING MULTILEVEL AND MULTIDISCIPLINARY MANAGEMENT OF HYPERTENSIVE DISORDERS OF PREGNANCY. A combination of strategies prepregnancy, antepartum, and postpartum can identify high-risk groups and patients at risk for developing HDP (**Figure 1**). Phone-based applications, blue-tooth or cellular upload of BP measurements to the EMR from BP self-monitoring, video-based EMR-integrated telemedicine, and CHWs could be integrated more fully to manage peripartum HDP (**Central Illustration**). Technology advances person-centered clinical care to increase health care access and empowers patients to engage in self-management for improved health outcomes. A model of prioritized health care access that meets each patient where they are as opposed to relying on the patient coming to the health system may be more useful to identify acutely uncontrolled BP both ante and postpartum. CHWs can provide enhanced health education and coaching, peer support, and streamline patient-provider communication, aiding therapeutic optimization. CHWs could be incorporated into the cardio-obstetrics team, as consensus guidelines encourage early involvement of the cardio-obstetrics team to prevent maternal morbidity and mortality.[70] Furthermore, an equity-focused approach is crucial, with dedicated CHWs responsible for overseeing and encouraging retention in routine care, completion of referrals to primary and specialty care postpartum, screening for social needs, and introducing community resources. Assessment of clinical and social needs and coordination of real-time care plan management will allow for earlier identification, timely intervention, and prevention of unnecessary readmission and use of emergent/hospital-based care, as well as morbidity from uncontrolled BP.

Combined interdisciplinary approach for patients with HDP has been found effective.[71] Interventions might include education for both providers discharging patients with HDP and patients with a diagnosis of HDP (by nurse educators or CHWs), the provision of free BP monitors to all patients with HDP,

CENTRAL ILLUSTRATION **Hypertensive Disorders of Pregnancy: Innovative Management Strategies**



Radparvar AA, et al. JACC Adv. 2024;3(3):100864.

Hypertensive disorders of pregnancy may be best addressed with a tripartite strategy using self-monitoring, technology-driven personalized medicine, and community health worker outreach to decrease adverse effects of uncontrolled blood pressure (BP) in the antepartum and postpartum periods.

scheduling of postpartum appointments prior to discharge, creation of a dedicated postpartum hypertension clinic, development of workflows and algorithms for those with HDP who present to the emergency department for evaluation, and potential readmission and development of workflows and algorithms for management of medication during the postpartum period. Implementation of this workflow and interventions can be associated with an increase in adherence to postpartum visit for follow-up for HDP.[71]

CONCLUSIONS

Combining elements of innovative management strategies like automated BP self-monitoring, telemedicine, and individualized care by CHW with an interdisciplinary and equity-focused approach could be the future in managing HDP. If successful, this model could be generalized across centers and across other aspects of care, with the overall goal of reducing maternal morbidity and mortality.

FUNDING SUPPORT AND AUTHOR DISCLOSURES

Dr Bortnick has received philanthropic research support from Dr Hazel J. Chambers; research support from the Resnick Emerging Scholars in Aging Award (Albert Einstein College of Medicine), and K23 HL146982 (National Heart, Lung, and Blood Institute); is site principal investigator for sponsored clinical trial by CSL-Behring, Inc for which her institution received compensation; has received a modest honorarium from ClearView Healthcare, LLC; has received

unrestricted educational grant and honorarium from Zoll, Inc to her institution; and has received honorarium and travel support to her institution from Getinge, Inc, all outside the published work. Dr Wolfe acknowledges support from R21 subaward HD101783. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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KEY WORDS antepartum, blood pressure, community, hypertensive, management, pregnancy, postpartum, telehealth