Current Hypertension Reports (2018) 20: 101
https://doi.org/10.1007/s11906-018-0901-z

BLOOD PRESSURE MONITORING AND MANAGEMENT (J COCKCROFT, SECTION EDITOR)

# Out of Office Blood Pressure Measurement in Pregnancy and the Postpartum Period

Natalie A. Bello[1,2] · Eliza Miller[3] · Kirsten Cleary[4] · Ronald Wapner[4] · Daichi Shimbo[1] · Alan T. Tita[5]

Published online: 25 October 2018
© Springer Science+Business Media, LLC, part of Springer Nature 2018

## Abstract

**Purpose** Hypertensive disorders of pregnancy are increasing in prevalence and associated with significant maternal and perinatal morbidity and mortality.

**Recent Findings** Increased emphasis has been placed recently on the use of out-of-office (i.e., home and ambulatory) blood pressure (BP) monitoring to diagnose and manage hypertension in the general population. Current guidelines offer limited recommendations on the use of out-of-office BP monitoring during pregnancy and postpartum.

**Summary** This review will discuss the recent literature on BP measurement outside of the office and its use for screening, diagnosis, and treatment in pregnancy and postpartum, and will illuminate areas for future research.

**Keywords** Hypertensive disorder of pregnancy · Preeclampsia · Post-partum hypertension · Home blood pressure · Ambulatory blood pressure

## Introduction

Hypertensive disorders of pregnancy (HDP) are among the most commonly encountered conditions in pregnancy, affecting up to 20% of pregnancies, and their prevalence is rising [1••, 2, 3]. HDP are classified as chronic hypertension (HTN) (diagnosed prior to pregnancy or before 20 weeks gestation), gestational HTN (isolated HTN diagnosed at 20 weeks gestation or later), preeclampsia/eclampsia [increase in blood pressure (BP) with concomitant proteinuria or organ damage], and preeclampsia superimposed on chronic HTN [4•] (Table 1). HDP are associated not only with an increased risk of adverse maternal and perinatal outcomes, some of which may be preventable with BP control during pregnancy, but also with an increased risk of future HTN, diabetes, stroke, and cardiovascular disease (CVD) [1••, 2, 5–9, 10•, 11•, 12, 13••, 14, 15••, 16, 17, 18••]. HTN often persists or worsens in the postpartum period and can also arise de novo in the first days to weeks following delivery [19•, 20, 21]. HTN is the leading cause of postpartum readmission in the United States [22]. Women with elevated postpartum BP and postpartum preeclampsia, in particular those with severe HTN, are at an increased risk of stroke, seizures, heart failure, and death [5, 7]. The early identification and treatment of women at risk for these adverse HTN-related events during pregnancy and in the puerperium is likely to meaningfully reduce maternal morbidity and mortality.

This article is part of the Topical Collection on *Blood Pressure Monitoring and Management*

✉ Natalie A. Bello
nb338@cumc.columbia.edu

[1] Department of Medicine, Columbia University Irving Medical Center, New York, NY, USA

[2] Division of Cardiology, Columbia University Irving Medical Center, 622 West 168th Street, PH 3-342, New York, NY 10032, USA

[3] Department of Neurology, Division of Stroke and Cerebrovascular Disease, Columbia University Irving Medical Center, New York, NY, USA

[4] Department of Obstetrics and Gynecology, Columbia University Irving Medical Center, New York, NY, USA

[5] Department of Obstetrics and Gynecology and Center for Women's Reproductive Health, University of Alabama at Birmingham, Birmingham, AL, USA

**Table 1** Classification of hypertensive disorders of pregnancy

| | |
|---|---|
| Chronic HTN | Elevated BP prior to pregnancy, before 20 weeks gestation, or persistently elevated postpartum BP > 6 weeks postpartum |
| Gestational HTN | Elevated BP after 20 weeks gestation in isolation that resolves by 6 week postpartum |
| Preeclampsia/eclampsia | Elevated BP with proteinuria, thrombocytopenia, impaired hepatic function, new renal insufficiency, pulmonary edema, visual or neurologic changes |
| Preeclampsia superimposed on chronic HTN | Chronic HTN in association with preeclampsia |

## Out of Office Blood Pressure Measurement During Pregnancy

The accurate determination of BP during pregnancy is essential, as both under- and over-treatment of HTN may result in harm to the mother and/or fetus [23••, 24]. Inadequate treatment increases the risk of placental abruption and maternal stroke, while over-treatment with antihypertensive medication can potentially reduce placental perfusion pressure resulting in placental insufficiency, fetal growth restriction, and premature delivery [1••, 25–28]. Currently, decisions surrounding antihypertensive therapy for most individuals with HTN, regardless of pregnancy status, are primarily based on office BP which is only a brief snapshot and a poor surrogate for a patient's "true" BP [29, 30]. There is increasing interest in the use of out-of-office BP to guide BP management in non-pregnant adults. As out-of-office BP represents BP in the natural environment, it could reflect placental perfusion pressure better than office BP and may be a target for therapy during pregnancy as well. Out-of-office BP monitoring includes ambulatory BP monitoring (ABPM), which records BP measurements every 15 to 30 min over 24 h, and home BP monitoring (HBPM) which requires a patient to self-measure BP at least twice daily for 3–7 days (Table 2). ABPM and HBPM can also be used to identify phenotypes defined by a mismatch between office and out-of-office BP [31, 32]. In some individuals not taking antihypertensive medications, BP outside of the office is lower than office BP, termed white coat HTN, while in others it may be higher outside of the office, a phenomenon called masked HTN.

## Accuracy of BP Devices in Pregnancy

Of note, the hemodynamic changes and peripheral edema associated with pregnancy, and preeclampsia in particular, may affect the accuracy of the algorithms used by oscillometric devices to measure BP [23••, 33••]. As such, guidelines recommend separately validating BP measurement devices for accuracy among pregnant women [34–36, 37••]. A systematic review of validation studies of office, ambulatory, and home BP measurement devices in pregnant women found 61% of devices specifically validated for use in pregnancy passed the validation study, though only 34% of studies were performed without any protocol violation [38••]. There are currently few ABPM or HBPM devices that have been consistently validated for accuracy in women with preeclampsia [38••, 39]. These devices are listed in Table 2.

## The Role of Out-Of-Office Blood Pressure Measurement in Pregnancy

### Screening for and Diagnosing HTN in Pregnancy

The United States Preventive Services Task Force (USPSTF) recently released a statement recommending providers obtain BP measurements during each prenatal care visit throughout the duration of pregnancy to screen for preeclampsia [40]. This recommendation is based on evidence that demonstrates the potential benefit from early detection of preeclampsia outweighs any potential harm associated with HTN treatment. There are currently no recommendations or guidelines from any society recommending the use of out-of-office BP measurement as a screening tool for HDP.

**Table 2** Office and out-of-office blood pressure measurement

| | | Advantages | Disadvantages | Validated Devices for Pregnancy [38••] |
|---|---|---|---|---|
| Office | | Established cut-offs for diagnosing HTN, widely available | Single point in time, "artificial" environment, white coat HTN | A&D UM-101, Dinamap ProCare, Nissei DS-00, Omron HEM 907, Omron MIT Elite |
| Out-of-office | ABPM | Awake and asleep readings, many measurements over 24 h, diagnose white coat and masked HTN | Limited availability, often unreimbursed, sleep disturbances | BP Lab, QuietTrak |
| | HBPM | Inexpensive, widely available, comfortable, easy to use and perform serially, diagnose white coat and masked HTN | Cut-offs not well-established, susceptible to erroneous use | WatchBP Home, Omron MIT, Omron MIT Elite |

In men and non-pregnant women with elevated office BP, both the USPSTF and the American College of Cardiology (ACC)/American Heart Association (AHA) recommend obtaining BP measurements outside of the office setting to confirm the diagnosis of HTN prior to initiating treatment [41, 42]. As out-of-office BP measurements have been shown to be consistently lower than office BP measurements, a different BP threshold has been established for elevated out-of-office BP and out-of-office HTN in non-pregnant adults. In contrast, two studies of HBPM in pregnancy found office and home measurements were similar in pregnant women [43, 44], while another found home measurements to be higher than office BP [45]. Despite several studies examining BP trends over the course of pregnancy using HBPM and ABPM, there are currently limited data describing ideal diagnostic out-of-office cut-points for HDP [46–53]. A recent study by Mikami et al. attempted to fill this gap and recommends trimester specific BP cut-off values in pregnancy that are lower than those recommended in non-pregnant adults [54]. Ideally, further studies examining HBPM values and maternal-fetal outcomes are needed before a definitive out-of-office BP threshold for the diagnosis of HDP can be recommended.

## White Coat HTN in Pregnancy

Currently, the only recommended use of ABPM in pregnancy is to confirm a diagnosis of suspected white coat HTN prior to initiating antihypertensive medication [1••]. Limited available data suggests that white coat HTN may affect from 30 to 70% of pregnant women [55, 56]. Compared to women with sustained HTN, defined as elevated office and out-of-office BP, women with white coat HTN had better pregnancy outcomes [57–59]. However, these studies were small, enrolled few women on antihypertensive medication, utilized ABPM devices of questionable validity in pregnancy, and did not adjust for potential confounders. These studies also found pregnant women with white coat HTN are not at increased risk for developing preeclampsia and have neonatal birth weights, rates of intrauterine growth restriction (IUGR), and hospital length of stay similar to women with sustained normotension (non-elevated office BP and non-elevated ambulatory BP). Cesarean section rates in women with white coat HTN are similar to those with sustained HTN (elevated office BP and elevated ambulatory BP), suggesting that office BP readings affect the decision-making processes leading to induction of labor and may lead to unnecessary cesarean deliveries. Although these studies suggest that identifying white coat HTN is important in pregnancy, most of these studies did not use ABPM devices that were specifically validated in pregnancy and their findings should be interpreted with caution.

Despite recommendations to use ABPM in pregnancy to diagnose white coat HTN, HBPM could be used in a similar manner. Although, as previously mentioned, diagnostic cut-offs for normative values of BP on HBPM during pregnancy have not been thoroughly vetted, several home BP monitors have been validated for use in pregnant women and can be utilized to identify women with elevated office BP and non-elevated out-of-office BP [38••, 60–62]. There are several advantages to the use of HBPM over ABPM for assessing white coat phenomena in pregnant women. Compared to ABPM, which is worn for only 24 h, HBPM captures "true" BP over a longer period of time, it has better reproducibility, is well tolerated, and does not interfere with sleep. HBPM is also more widely available and less costly than ABPM [63].

## Masked Hypertension in Pregnancy

Although data are limited, approximately 33% of pregnant women with a history of HDP, diabetes, or active smoking who are not taking antihypertensive medications have been reported to have elevated out-of-office BP on ABPM, despite normal office BP [64••, 65]. Masked HTN in non-pregnant adults is an area of active investigation, as its presence is associated with a cardiovascular risk profile similar to that of office HTN [66]. Hermida et al. reported lower rates of preterm delivery and IUGR in women with masked HTN when office BP was normal compared to when office BP was elevated [65]. Future research is needed to better define the prevalence of masked HTN, use of HBPM vs. ABPM for diagnosis, and the associations of masked HTN with clinical endpoints in pregnancy.

## When to Perform BP Monitoring in Pregnancy

Several hemodynamic adaptations occur as pregnancy progresses. Vasodilation and a drop in systemic vascular resistance are a hallmark of the first trimester, following which cardiac output and heart rate increase. In pregnancies not affected by HDP, BP increases in the third trimester and may normalize to a pre-pregnancy value by term. To monitor for the development of HDP, BP is checked at least monthly in all pregnant women as a routine part of obstetric practice, and more frequently in women with elevated BP [1••]. Current American College of Obstetrics and Gynecology (ACOG) recommendations for the use of HBPM in pregnancy include at least weekly home measurement in women with gestational HTN, and its use is also suggested for women with chronic HTN and poorly controlled blood pressure [1••]. It is important to note that similar to office BP measurement, proper HBPM technique including correct cuff size and positioning as well as an adequate rest period and the use of repeated measurements is required for accuracy. ABPM is less likely to be affected by measurement error as the devices are fitted in the office and programmed to obtain BP at fixed intervals over 24 h.

## Monitoring Response to Antihypertensive Therapy

Evidence from randomized controlled trials shows that antihypertensive medications can reduce the risk of CVD events and mortality among men and non-pregnant women with HTN [42]. However, few well-designed studies have been conducted examining the effects of antihypertensive medication on maternal and fetal outcomes in pregnant women with HTN [11•, 67, 68]. Expert opinion from guidelines indicates that pregnant women should be treated with antihypertensive medications for systolic/diastolic office BP ≥ 160/105–110 mmHg. However, the effects of antihypertensive medication in pregnant women with mild to moderate HTN (systolic/diastolic OBP < 160/105–110 mmHg) are controversial [69, 70]. There may be unintended harm of antihypertensive medication to the fetus during pregnancy because of a reduction in plasma volume, electrolyte disturbance, decreased uteroplacental blood flow, or fetal growth retardation. A meta-analysis of studies including 4723 pregnant women with mild to moderate HTN was inconclusive regarding whether antihypertensive medication had a benefit or harm on important pregnancy outcomes beyond reducing progression to severe HTN, such as preeclampsia, small for gestational age babies, preterm birth, and fetal death [71]. The Control of Hypertension in Pregnancy Study (CHIPS) found no significant difference in maternal or fetal outcomes between tight BP control (target diastolic OBP of 85 mmHg) and a more lenient (less-tight) strategy (target diastolic OBP of 100 mmHg) in 987 women with HTN at enrollment, defined as a diastolic OBP of 90–105 mmHg or 85–105 mmHg if taking antihypertensive medications [11•]. There were no differences in the risk of pregnancy loss, need for high-level neonatal care, or overall maternal complications between the groups, although more women in the less-tight control group were more likely to have severe HTN. Additional ongoing studies are examining the effectiveness and safety of a BP treatment strategy for mild chronic HTN during pregnancy to a goal recommended for non-pregnant adults (systolic/diastolic OBP < 140/90 mmHg) as compared with no treatment unless HTN is severe.

Future studies investigating the conduct of HBPM and ABPM in pregnant women who are taking antihypertensive medication are needed to clarify how office BP and out-of-office BP should be factored into balanced management of HTN in pregnancy. For example, the relatively high prevalence of white coat HTN with its associated benign prognosis must be balanced against missing masked HTN with a potentially treatable excessive risk.

## Role of Out-of-Office Blood Pressure Measurement in the Postpartum Period

There is a paucity of data regarding the evaluation and management of BP in the postpartum period (first 6–12 weeks following delivery when the physiologic changes due to pregnancy recede [72]. In a group of 203 women with planned postpartum inpatient stays of 1 week or longer, 12% of previously normotensive women became hypertensive and > 50% of women with HDP had a systolic/diastolic BP ≥ 150/100 mmHg [20, 21] in the postpartum period. A more recent study examining women admitted for cesarean section of a singleton pregnancy found 18.6% of women developed postpartum HTN, and 41.8% of these cases were de novo HTN [19•]. Guidelines suggest BP monitoring in the first 72 h postpartum and 7 to 10 days after delivery for women with HDP, although the supporting evidence is of poor quality [1••]. In practice, many women, especially those with mild HTN, may be discharged prior to 72 h and may not return for a BP check until a routine 6-week postpartum visit, resulting in missed opportunities for BP measurement and management.

Postpartum HTN, both in isolation and as a manifestation of preeclampsia, is one of the most important risk factors for the development of postpartum stroke [73]. Intracerebral hemorrhage is the single greatest cause of death in women with preeclampsia [74]. Recent efforts to redefine and optimize postpartum care into a continuum propose that all women have contact with a provider within the first 3 weeks postpartum, and those with HTN should have their BP evaluated in 3–10 days [75]. An approach to monitoring postpartum BP after discharge that minimizes patient burden and office visits may enhance identification of women with poorly controlled BP, and prevent potential adverse HTN-related events. HBPM is affordable, widely available, well-tolerated, easy to use, and validated to capture BP over an extended period of time [63]. HBPM also has the potential to minimize unnecessary visits for office BP measurement. As such, the measurement of out-of-office BP using HBPM may play an essential role in postpartum care.

## Knowledge Gaps

Several important knowledge gaps and a lack of well-validated devices in women with preeclampsia limit the widespread use of out-of-office BP measurement for the management of HDP. ACOG guidelines endorse the use of HBPM throughout pregnancy in women with HTN, but do not specify how HBPM should be performed [1••]. There are scarce data on the minimum duration of HBPM required to reliably estimate mean home BP. Additionally, the long-term adherence to and tolerability of HBPM in pregnancy is unknown. A few prior studies of HBPM have found short-term adherence rates ranging from 73 to 96% (days to weeks) [45, 56, 76••], but long-term (weeks to months) adherence to HBPM has not been examined. Thus, the best approach for conducting HBPM in women with HDP remains unknown.

In addition to a lack of well-validated ABPM devices for use in pregnancy, there is a need for a head to head evaluation of the use of ABPM vs. HBPM to examine their respective sensitivities and specificities for the diagnosis of white coat and masked HTN, and the relation with important maternal-neonatal outcomes. These knowledge gaps have important potential clinical implications for pregnant women, and answering them could provide valuable information regarding the optimal use of out-of-office BP measurement in pregnancy.

There are many knowledge gaps in the monitoring, diagnosis, and treatment of postpartum HTN. There are scant contemporary data on the normal postpartum range of blood pressure. As a result, it is currently unclear who is at risk for the development of de novo postpartum HTN and could benefit from out-of-office BP measurement. Additionally, future studies of postpartum BP are needed to determine optimal postpartum target BP level and medication escalation/de-escalation treatment strategies.

## Future Directions

Currently, clinicians rely primarily on office BP to make decisions on initiating and adjusting antihypertensive medication in pregnancy. However, out-of-office BP measurement offers a promising target for future studies of BP management in pregnant and postpartum women with HTN. Presently, it is unknown whether a reduction in ambulatory BP during treatment with antihypertensive medication has a stronger association with perinatal outcomes than OBP.

## Conclusions

HTN is an increasingly common complication of pregnancy and the postpartum period that is associated with substantial maternal-perinatal morbidity and mortality. Pregnancy is associated with dynamic BP changes, and the accurate measurement of BP is critically important for the well-being of the mother and fetus [23••, 24]. The adjunctive use of out-of-office BP monitoring may help identify pregnant women with masked hypertension who may derive the most benefit from antihypertensive medication intensification, as well as women with white coat phenomena in whom antihypertensive medication intensification may be detrimental. Out-of-office BP measurement, including the use of home and ambulatory monitoring, is an invaluable tool to aid in guiding the diagnosis and management of HDP. The potentially high prevalence of white coat HTN and its benign prognosis in pregnancy, and the possible harm associated with antihypertensive medication on perinatal outcomes highlight the benefits of using out-of-office BP in addition to office BP to guide HTN diagnosis and treatment in pregnancy.

**Sources of Funding** This work was supported by K23-HL136853 (NAB) KL2TR001874 (EM) from the NIH and NCATS and K24 HL125704 (DS) from the National Heart, Lung, and Blood Institute (NHLBI) at the National Institutes of Health (NIH).

**Authors' Contributions** All authors contributed to the manuscript writing and revision. All authors have read and approved the final version of the manuscript.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare no conflicts of interest relevant to this manuscript.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

## References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1.•• Hypertension in pregnancy. Report of the American College of Obstetricians and Gynecologists' Task Force on Hypertension in Pregnancy. Obstetrics and gynecology. 2013;122(5):1122–31. doi: https://doi.org/10.1097/01.aog.0000437382.03963.88.
2. Berg CJ, Mackay AP, Qin C, Callaghan WM. Overview of maternal morbidity during hospitalization for labor and delivery in the United States: 1993-1997 and 2001-2005. Obstet Gynecol. 2009;113(5):1075–81. https://doi.org/10.1097/AOG.0b013e3181a09fc0.
3. Umesawa M, Kobashi G. Epidemiology of hypertensive disorders in pregnancy: prevalence, risk factors, predictors and prognosis. Hypertens Res. 2017;40(3):213–20. https://doi.org/10.1038/hr.2016.126.
4.• Sutton ALM, Harper LM, Tita ATN. Hypertensive disorders in pregnancy. Obstet Gynecol Clin N Am. 2018;45(2):333–47. https://doi.org/10.1016/j.ogc.2018.01.012.
5. Kuklina EV, Ayala C, Callaghan WM. Hypertensive disorders and severe obstetric morbidity in the United States. Obstet Gynecol. 2009;113(6):1299–306. https://doi.org/10.1097/AOG.0b013e3181a45b25.
6. Callaghan WM, Creanga AA, Kuklina EV. Severe maternal morbidity among delivery and postpartum hospitalizations in the United States. Obstet Gynecol. 2012;120(5):1029–36. https://doi.org/10.1097/AOG.0b013e31826d60c5.
7. Leffert LR, Clancy CR, Bateman BT, Bryant AS, Kuklina EV. Hypertensive disorders and pregnancy-related stroke: frequency, trends, risk factors, and outcomes. Obstet Gynecol. 2015;125(1):124–31. https://doi.org/10.1097/aog.0000000000000590.
8. Roberts JM, Pearson GD, Cutler JA, Lindheimer MD. Summary of the NHLBI working group on research on hypertension during pregnancy. Hypertension in pregnancy. 2003;22(2):109–27. https://doi.org/10.1081/prg-120016792.

9. Creanga AA, Berg CJ, Syverson C, Seed K, Bruce FC, Callaghan WM. Pregnancy-related mortality in the United States, 2006-2010. Obstet Gynecol. 2015;125(1):5–12. https://doi.org/10.1097/aog.0000000000000564.
10.• Say L, Chou D, Gemmill A, Tuncalp O, Moller AB, Daniels J, et al. Global causes of maternal death: a WHO systematic analysis. Lancet Glob Health. 2014;2(6):e323–33. https://doi.org/10.1016/s2214-109x(14)70227-x.
11.• Magee LA, von Dadelszen P, Rey E, Ross S, Asztalos E, Murphy KE, et al. Less-tight versus tight control of hypertension in pregnancy. N Engl J Med. 2015;372(5):407–17. https://doi.org/10.1056/NEJMoa1404595.
12. Garovic VD, August P. Preeclampsia and the future risk of hypertension: the pregnant evidence. Curr Hypertens Rep. 2013;15(2):114–21. https://doi.org/10.1007/s11906-013-0329-4.
13.•• Wu P, Haththotuwa R, Kwok CS, Babu A, Kotronias RA, Rushton C et al. Preeclampsia and future cardiovascular health: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcome. 2017;10(2). doi:https://doi.org/10.1161/circoutcomes.116.003497.
14. Mosca L, Benjamin EJ, Berra K, Bezanson JL, Dolor RJ, Lloyd-Jones DM, et al. Effectiveness-based guidelines for the prevention of cardiovascular disease in women–2011 update: a guideline from the American Heart Association. J Am Coll Cardiol. 2011;57(12):1404–23. https://doi.org/10.1016/j.jacc.2011.02.005.
15.•• Dunietz GL, Strutz KL, Holzman C, Tian Y, Todem D, Bullen BL, et al. Moderately elevated blood pressure during pregnancy and odds of hypertension later in life: the POUCHmoms longitudinal study. BJOG: Int J Obstet Gynaecol. 2017;124:1606–13. https://doi.org/10.1111/1471-0528.14556.
16. Mannisto T, Mendola P, Vaarasmaki M, Jarvelin MR, Hartikainen AL, Pouta A, et al. Elevated blood pressure in pregnancy and subsequent chronic disease risk. Circulation. 2013;127(6):681–90. https://doi.org/10.1161/circulationaha.112.128751.
17. Lykke JA, Langhoff-Roos J, Sibai BM, Funai EF, Triche EW, Paidas MJ. Hypertensive pregnancy disorders and subsequent cardiovascular morbidity and type 2 diabetes mellitus in the mother. Hypertension (Dallas, Tex : 1979). 2009;53(6):944–51. https://doi.org/10.1161/hypertensionaha.109.130765.
18.•• Tooher J, Thornton C, Makris A, Ogle R, Korda A, Hennessy A. All hypertensive disorders of pregnancy increase the risk of future cardiovascular disease. Hypertension (Dallas, Tex : 1979). 2017;70(4):798–803. https://doi.org/10.1161/hypertensionaha.117.09246.
19.• Goel A, Maski MR, Bajracharya S, Wenger JB, Zhang D, Salahuddin S, et al. Epidemiology and mechanisms of de novo and persistent hypertension in the postpartum period. Circulation. 2015;132(18):1726–33. https://doi.org/10.1161/circulationaha.115.015721.
20. Walters BN, Thompson ME, Lee A, de Swiet M. Blood pressure in the puerperium. Clin Sci (London, England : 1979). 1986;71(5):589–94.
21. Walters BN, Walters T. Hypertension in the puerperium. Lancet (London, England). 1987;2(8554):330.
22. Clapp MA, Little SE, Zheng J, Robinson JN. A multi-state analysis of postpartum readmissions in the United States. Am J Obstet Gynecol. 2016;215(1):113.e1–e10. https://doi.org/10.1016/j.ajog.2016.01.174.
23.•• Nathan HL, Duhig K, Hezelgrave NL, Chappell LC, Shennan AH. Blood pressure measurement in pregnancy. Obstet Gynaecol. 2015;17(2):91–8. https://doi.org/10.1111/tog.12173.
24. Shennan AH, Halligan AW. Measuring blood pressure in normal and hypertensive pregnancy. Best Pract Res Clin Obstet Gynaecol. 1999;13(1):1–26.
25. ACOG Practice Bulletin. Chronic hypertension in pregnancy. ACOG committee on practice bulletins. Obstet Gynecol. 2001;98(1):suppl 177–185.
26. Sibai BM, Lindheimer M, Hauth J, Caritis S, VanDorsten P, Klebanoff M, et al. Risk factors for preeclampsia, abruptio placentae, and adverse neonatal outcomes among women with chronic hypertension. National Institute of Child Health and Human Development network of maternal-fetal medicine units. N Engl J Med. 1998;339(10):667–71. https://doi.org/10.1056/nejm199809033391004.
27. Meis PJ, Goldenberg RL, Mercer BM, Iams JD, Moawad AH, Miodovnik M, et al. The preterm prediction study: risk factors for indicated preterm births. Maternal-fetal medicine units network of the National Institute of Child Health and Human Development. Am J Obstet Gynecol. 1998;178(3):562–7.
28. Harper LM, Biggio JR, Anderson S, Tita AT. Gestational age of delivery in pregnancies complicated by chronic hypertension. Obstet Gynecol. 2016;127(6):1101–9. https://doi.org/10.1097/aog.0000000000001435.
29. James PA, Oparil S, Carter BL, Cushman WC, Dennison-Himmelfarb C, Handler J, et al. 2014 evidence-based guideline for the management of high blood pressure in adults: report from the panel members appointed to the eighth joint national committee (jnc 8). JAMA. 2014;311(5):507–20. https://doi.org/10.1001/jama.2013.284427.
30. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, et al. Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. Hypertension (Dallas, Tex : 1979). 2005;45(1):142–61.
31. Pickering TG, Shimbo D, Haas D. Ambulatory blood-pressure monitoring. N Engl J Med. 2006;354(22):2368–74. https://doi.org/10.1056/NEJMra060433.
32. Shimbo D, Abdalla M, Falzon L, Townsend RR, Muntner P. Studies comparing ambulatory blood pressure and home blood pressure on cardiovascular disease and mortality outcomes: a systematic review. J Am Soc Hypertens: JASH. 2015;10:224–234.e17. https://doi.org/10.1016/j.jash.2015.12.013.
33.•• Stergiou GS, Dolan E, Kollias A, Poulter NR, Shennan A, Staessen JA, et al. Blood pressure measurement in special populations and circumstances. J Clin Hypertens. 2018;20(7):1122–7. https://doi.org/10.1111/jch.13296.
34. O'Brien E, Atkins N, Stergiou G, Karpettas N, Parati G, Asmar R, et al. European Society of Hypertension International Protocol revision 2010 for the validation of blood pressure measuring devices in adults. Blood Press Monit. 2010;15(1):23–38. https://doi.org/10.1097/MBP.0b013e3283360e98.
35. O'Brien E, Petrie J, Littler W, de Swiet M, Padfield PL, Altman DG, et al. An outline of the revised British Hypertension Society protocol for the evaluation of blood pressure measuring devices. J Hypertens. 1993;11(6):677–9.
36. Non-invasive sphygmomanometers - part 2: clinical investigation of automated measurement type. American National Standards Institute. ANSI/AAMI/ISO 81060-2;2013. http://webstore.ansi.org.
37.•• Stergiou GS, Alpert B, Mieke S, Asmar R, Atkins N, Eckert S, et al. A universal standard for the validation of blood pressure measuring devices: Association for the Advancement of Medical Instrumentation/European Society of Hypertension/International Organization for Standardization (AAMI/ESH/ISO) collaboration statement. Hypertension (Dallas, Tex : 1979). 2018;71(3):368–74. https://doi.org/10.1161/hypertensionaha.117.10237.
38.•• Bello NA, Woolley JJ, Cleary KL, Falzon L, Alpert BS, Oparil S, et al. Accuracy of blood pressure measurement devices in pregnancy: a systematic review of validation studies. Hypertension (Dallas, Tex : 1979). 2017. https://doi.org/10.1161/hypertensionaha.117.10295.

39. Hodgkinson JA, Sheppard JP, Heneghan C, Martin U, Mant J, Roberts N, et al. Accuracy of ambulatory blood pressure monitors: a systematic review of validation studies. J Hypertens. 2013;31(2): 239–50. https://doi.org/10.1097/HJH.0b013e32835b8d8b.
40. U.S. Preventive Services Task Force. Screening for preeclampsia: US preventive services task force recommendation statement. JAMA. 2017;317(16):1661–7. https://doi.org/10.1001/jama.2017.3439.
41. Siu AL. Screening for high blood pressure in adults: U.S. Preventive Services Task Force recommendation statement. Ann Intern Med. 2015;163(10):778–86. https://doi.org/10.7326/m15-2223.
42. Whelton PK, Carey RM, Aronow WS, Casey DE Jr, Collins KJ, Dennison Himmelfarb C, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol. 2017;71:e127–248. https://doi.org/10.1016/j.jacc.2017.11.006.
43. Tucker KL, Taylor KS, Crawford C, Hodgkinson JA, Bankhead C, Carver T, et al. Blood pressure self-monitoring in pregnancy: examining feasibility in a prospective cohort study. BMC Pregnancy Childbirth. 2017;17(1):442. https://doi.org/10.1186/s12884-017-1605-0.
44. Naef RW 3rd, Perry KG Jr, Magann EF, McLaughlin BN, Chauhan SP, Morrison JC. Home blood pressure monitoring for pregnant patients with hypertension. J Perinatol. 1998;18(3):226–9.
45. Lo C, Taylor RS, Gamble G, McCowan L, North RA. Use of automated home blood pressure monitoring in pregnancy: is it safe? Am J Obstet Gynecol. 2002;187(5):1321–8.
46. Brown MA, Robinson A, Bowyer L, Buddle ML, Martin A, Hargood JL, et al. Ambulatory blood pressure monitoring in pregnancy: what is normal? Am J Obstet Gynecol. 1998;178(4):836–42.
47. Dalton KJ, Manning K, Robarts PJ, Dripps JH, Currie JR. Computerized home telemetry of maternal blood pressure in hypertensive pregnancy. Int J Biomed Comput. 1987;21(3–4):175–87.
48. Eguchi K, Ohmaru T, Ohkuchi A, Hirashima C, Takahashi K, Suzuki H, et al. Ambulatory BP monitoring and clinic BP in predicting small-for-gestational-age infants during pregnancy. J Hum Hypertens. 2016;30(1):62–7. https://doi.org/10.1038/jhh.2015.20.
49. Metoki H, Ohkubo T, Obara T, Akutsu K, Yamamoto M, Ishikuro M, et al. Daily serial hemodynamic data during pregnancy and seasonal variation: the BOSHI study. Clin Exp Hypertens. 2012;34(4):290–6. https://doi.org/10.3109/10641963.2012.681086.
50. Rey E, Morin F, Boudreault J, Pilon F, Vincent D, Ouellet D. Blood pressure assessments in different subtypes of hypertensive pregnant women: office versus home patient- or nurse-measured blood pressure. Hypertens Pregnancy. 2009;28(2):168–77. https://doi.org/10.1080/10641950802233072.
51. Rey E, Pilon F, Boudreault J. Home blood pressure levels in pregnant women with chronic hypertension. Hypertens Pregnancy. 2007;26(4):403–14.
52. Ochsenbein-Kolble N, Roos M, Gasser T, Huch R, Huch A, Zimmermann R. Cross sectional study of automated blood pressure measurements throughout pregnancy. BJOG Int J Obstet Gynaecol. 2004;111(4):319–25.
53. Denolle T, Daniel JC, Calvez C, Ottavioli JN, Esnault V, Herpin D. Home blood pressure during normal pregnancy. Am J Hypertens. 2005;18(9 Pt 1):1178–80.
54. Mikami Y, Takai Y, Era S, Ono Y, Saitoh M, Baba K, et al. Provisional criteria for the diagnosis of hypertension in pregnancy using home blood pressure measurements. Hypertens Res. 2017;40(7):679–84. https://doi.org/10.1038/hr.2017.6.
55. Peek M, Shennan A, Halligan A, Lambert PC, Taylor DJ, De Swiet M. Hypertension in pregnancy: which method of blood pressure measurement is most predictive of outcome? Obstet Gynecol. 1996;88(6):1030–3. https://doi.org/10.1016/s0029-7844(96)00350-x.
56. Denolle T, Weber JL, Calvez C, Getin Y, Daniel JC, Lurton O, et al. Diagnosis of white coat hypertension in pregnant women with teletransmitted home blood pressure. Hypertens Pregnancy. 2008;27(3):305–13. https://doi.org/10.1080/10641950802000950.
57. Bar J, Maymon R, Padoa A, Wittenberg C, Boner G, Ben-Rafael Z, et al. White coat hypertension and pregnancy outcome. J Hum Hypertens. 1999;13(8):541–5.
58. Bellomo G, Narducci PL, Rondoni F, Pastorelli G, Stangoni G, Angeli G, et al. Prognostic value of 24-hour blood pressure in pregnancy. JAMA. 1999;282(15):1447–52.
59. Brown MA, Robinson A, Jones M. The white coat effect in hypertensive pregnancy: much ado about nothing? Br J Obstet Gynaecol. 1999;106(5):474–80.
60. Reinders A, Cuckson AC, Lee JT, Shennan AH. An accurate automated blood pressure device for use in pregnancy and pre-eclampsia: the Microlife 3BTO-A. BJOG Int J Obstet Gynaecol. 2005;112(7):915–20.
61. de Greeff A, Beg Z, Gangji Z, Dorney E, Shennan AH. Accuracy of inflationary versus deflationary oscillometry in pregnancy and pre-eclampsia: OMRON-MIT versus OMRON-M7. Blood Press Monit. 2009;14(1):37–40. https://doi.org/10.1097/MBP.0b013e32831e305d.
62. Chung Y, de Greeff A, Shennan A. Validation and compliance of a home monitoring device in pregnancy: microlife WatchBP home. Hypertens Pregnancy. 2009;28(3):348–59. https://doi.org/10.1080/10641950802601286.
63. Shimbo D, Abdalla M, Falzon L, Townsend RR, Muntner P. Role of ambulatory and home blood pressure monitoring in clinical practice: a narrative review. Ann Intern Med. 2015;163(9):691–700. https://doi.org/10.7326/m15-1270.
64.•• Salazar MR, Espeche WG, Leiva Sisnieguez BC, Balbin E, Leiva Sisnieguez CE, Stavile RN, et al. Significance of masked and nocturnal hypertension in normotensive women coursing a high-risk pregnancy. J Hypertens. 2016;34(11):2248–52. https://doi.org/10.1097/hjh.0000000000001067.
65. Hermida RC, Ayala DE. Prognostic value of office and ambulatory blood pressure measurements in pregnancy. Hypertension (Dallas, Tex : 1979). 2002;40(3):298–303.
66. Anstey DE, Pugliese D, Abdalla M, Bello NA, Givens R, Shimbo D. An update on masked hypertension. Curr Hypertens Rep. 2017;19(12):94. https://doi.org/10.1007/s11906-017-0792-4.
67. Sibai BM, Mabie WC, Shamsa F, Villar MA, Anderson GD. A comparison of no medication versus methyldopa or labetalol in chronic hypertension during pregnancy. Am J Obstet Gynecol. 1990;162(4):960–6 discussion 6-7.
68. El Guindy AA, Nabhan AF. A randomized trial of tight vs. less tight control of mild essential and gestational hypertension in pregnancy. J Perinat Med. 2008;36(5):413–8. https://doi.org/10.1515/jpm.2008.060.
69. Fabregues G, Alvarez L, Varas Juri P, Drisaldi S, Cerrato C, Moschettoni C, et al. Effectiveness of atenolol in the treatment of hypertension during pregnancy. Hypertension (Dallas, Tex : 1979). 1992;19(2 Suppl):Ii129–31.
70. Podymow T, August P. Update on the use of antihypertensive drugs in pregnancy. Hypertension (Dallas, Tex : 1979). 2008;51(4):960–9. https://doi.org/10.1161/hypertensionaha.106.075895.
71. Abalos E, Duley L, Steyn DW. Antihypertensive drug therapy for mild to moderate hypertension during pregnancy. Cochrane

Database Syst Rev. 2014;2:Cd002252. https://doi.org/10.1002/14651858.CD002252.pub3.

72. Sibai BM. Etiology and management of postpartum hypertension-preeclampsia. Am J Obstet Gynecol. 2012;206(6):470–5. https://doi.org/10.1016/j.ajog.2011.09.002.
73. Crovetto F, Somigliana E, Peguero A, Figueras F. Stroke during pregnancy and pre-eclampsia. Curr Opin Obstet Gynecol. 2013;25(6):425–32. https://doi.org/10.1097/gco.0000000000000024.
74. Hasegawa J, Ikeda T, Sekizawa A, Tanaka H, Nakata M, Murakoshi T, et al. Maternal death due to stroke associated with pregnancy-induced hypertension. Circulation Journal. 2015;79(8):1835–40. https://doi.org/10.1253/circj.CJ-15-0297.
75. Committee Opinion No ACOG. 736: optimizing postpartum care. Obstet Gynecol. 2018;131(5):e140–e50. https://doi.org/10.1097/aog.0000000000002633.
76.•• Ishikuro M, Obara T, Metoki H, Ohkubo T, Yamamoto M, Akutsu K, et al. Blood pressure measured in the clinic and at home during pregnancy among nulliparous and multiparous women: the BOSHI study. Am J Hypertens. 2013;26(1):141–8. https://doi.org/10.1093/ajh/hps002.