Title: A remote postpartum blood pressure surveillance and reminder system for hypertensive disorders of pregnancy: a randomized clinical trial

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1. Proposal abstract

The overarching goals of our study are to (i) assess whether implementation of a Bluetooth-enabled remote blood pressure monitoring system improves monitoring of women with hypertensive disorders of pregnancy (HDP) in the postpartum period, (ii) assess whether improved monitoring improves blood pressure control and reduces morbidity in this patient population and (iii) evaluate the factors associated with poor postpartum follow up among patients with HDP. HDP, an umbrella term which includes chronic hypertension with or without superimposed preeclampsia, gestational hypertension, preeclampsia with or without severe features, HELLP syndrome and eclampsia, affect nearly 10% of pregnancies and are some of the most common conditions encountered by obstetricians.[1] In the postpartum period, hypertension can be related to persistence of pre-existing HDP, or it can develop de novo postpartum.[2] HDP are an important cause of maternal morbidity and mortality, and a leading cause of postpartum readmission.[3] Therefore, the American College of Obstetricians and Gynecologists (ACOG) recommends that in women with HDP, blood pressure should be monitored inpatient or with equivalent outpatient surveillance for at least 72 hours postpartum and again at 7-10 days after delivery.[1] The majority of patients, however, are discharged on postpartum day 2 or 3, often prior to this 72-hour mark and almost always prior to the 7-10 day mark. Even if they are discharged home with a plan for outpatient surveillance and follow-up, postpartum follow-up rates are known to be low: in one secondary analysis of postpartum follow-up and persistent hypertension in women with severe preeclampsia, the 6-week follow-up rate was 52%. Of those patients who did follow up, 21% had persistent hypertension.[4] With low-follow up rates and high rates of persistent hypertension in those that do follow up, clearly there is a large subset of women with continued hypertension who are simply lost to care. Barriers to care for women in the postpartum period include lack of consistent provider, lack of understanding of discharge instructions and difficulties with transportation. Additionally, many women have difficulty managing their own health issues when also taking care of a newborn.[5] Therefore, a proactive approach to monitoring BP as an outpatient in the postpartum period that involves minimal patient burden is needed to identify women with poorly controlled BP, adjust antihypertensive medications, and prevent hypertension-associated morbidity.

Remote blood pressure monitoring offers a possible solution to this problem. In a randomized control trial design, we propose to use a Philips Remote Patient Monitoring (RPM) System to assess whether we can improve blood pressure monitoring during this critical period. RPM has been shown repeatedly in the non-obstetric literature to improve hypertension management by increasing the amount of patients' involvement in their own care, and providing physicians with more dynamic control of patients' blood pressure.[6] We hypothesize that a Bluetooth-enabled blood pressure monitoring system will lead to closer monitoring and improved communication

between patients and their providers. Ultimately, we hypothesize that this will lead to earlier initiation and more active titration of anti-hypertensive medications, earlier recognition of and intervention for women at risk of significant hypertension-related morbidity and decreased rates of maternal morbidity and mortality.

2. Proposal body

2.1 Background

There is a paucity of data on the diagnosis and management of HDP in the postpartum period. The natural history of postpartum HDP is poorly understood, and estimates of the prevalence of the disease vary widely, ranging from 0.3 to 27.5%.[7] In older studies of patients who had 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.[8,9] Since those studies were performed, the length of a hospital admission for delivery has shortened. Most women are now discharged within 48-72 hours of delivery, and many are not evaluated again until their traditional 6-week postpartum visit. However, nearly 20% of women who deliver a baby in the United States will be seen and discharged from an emergency department prior to their traditional 6-week postpartum visit, and an additional 1-2% of patients will be admitted.[10] In a 2016 study, hypertension was found to be the second most common cause of postpartum readmission in the United States, after infection.[11] Short-term complications that are known to occur secondary to uncontrolled HDP include stroke, seizure, pulmonary edema, posterior reversible encephalopathy syndrome, renal or hepatic dysfunction, and death.[12] HDP is also a risk factor for the long-term development of cardiovascular disease, hypertension, stroke and renal disease.[13] Given all of these associated short-and long-term morbidities, close follow up of women with HDP is essential in the postpartum period and beyond. Yet due to the scarceness of empiric data on postpartum BP, there are limited recommendations regarding the initiation, frequency, and duration of postpartum BP monitoring in women with HDP.[14]

ACOG guidelines recommend that in women with HDP, blood pressure should be monitored in the hospital or with equivalent outpatient surveillance for at least 72 hours postpartum and again 7-10 days after delivery, or earlier in women with symptoms.[1] At CUIMC, the usual care for discharge of patients with HDP at CUIMC involves the following (hereafter referred to as "usual care"):

1. A prescription for a blood pressure cuff and instructions to measure blood pressures twice daily at home. *No make or model is specified, and the patient is responsible for obtaining the device from a pharmacy*.
2. Arrangements for a nursing service to visit the patient's home for a blood pressure check within the first few days after discharge. *The exact timing of this is not standardized; for example, if the patient is discharged on Friday, the nurse may come 72 hours later on Monday; if the patient is discharged on Thursday, the nurse may come 24 hours later on Friday.*
3. An appointment for a blood pressure check in the clinic where the patient received prenatal care at 7-10 days postpartum; the patient is instructed to bring logs of their twice daily blood pressure measurements to this visit. *Patients with private insurance are told to make this appointment with their prenatal care provider but are not given the*

appointment prior to discharge. Patients who are discharged on or after 7 days postpartum are told to follow up in one week

4. An appointment for a 6-week postpartum visit. *Patients with private insurance are told to make this appointment with their prenatal care provider but are not given the appointment prior to discharge.*

If followed in full by the patient, these policies do follow the current guidelines set forth by ACOG. However, extrapolating from the limited published data regarding follow-up rates and from approximations from our own publicly-insured population, it is reasonable to presume that only about half of these patients present for their one-week blood pressure check appointment.[15] Poor follow-up is not a problem unique to our institution. In a secondary analysis of factors associated with postpartum follow-up and persistent hypertension in women with severe preeclampsia by Levine et al, the 6-week follow-up rate was 52%. Among those with 6-week follow-up, 21% had persistent hypertension.[4] With low-follow up rates and high rates of persistent hypertension in those that do follow up, clearly there is a large subset of women with continued hypertension who are simply lost to care. Barriers to care in the postpartum period include lack of a consistent provider, lack of understanding of discharge instructions whether due to poor health literacy, a language difference or a failure of the provider to properly explain instructions, and difficulties with transportation. Additionally, many women have difficulty managing their own health issues when also taking care of a newborn, possibly with limited support.[16]

Postpartum care in general in the United States leaves something to be desired, and has been the subject of many studies aiming to determine how we can improve delivery of care to these patients.[17] In May of 2018, citing the urgent need to reduce severe maternal morbidity and mortality in the United States, ACOG released a committee opinion on the "fourth trimester," referring to the critical but oft-neglected postpartum period. It proposes a restructuring of postpartum care from a single visit at the 6-week mark to an ongoing process with services and support tailored to each woman's individual needs. Women with HDP should have blood pressure evaluation within 7-10 days postpartum, and women with severe hypertension should be seen within 72 hours.[18] Blood pressure assessment in this time period is critical, as more than 50% of postpartum strokes occur within 10 days of discharge.[19] Early identification and treatment of women with poorly controlled HDP could meaningfully reduce the hypertension-associated morbidity and mortality in this population.

Mobile health technologies have been shown to be useful, both in improving outcomes and in improving patient connectedness to care, both in obstetrics and in other disciplines.[20,21] In the non-obstetric population, RPM has been shown to improve treatment of hypertension.[6] RPM has also been studied in pregnancy and the postpartum period in limited contexts. In one such study, where patients self-selected into an RPM program for blood pressure monitoring postpartum, RPM patients reported fewer perceived barriers to care than their usual-care counterparts.[22] In another, women randomized to text-based reminders to check blood pressures had a significantly higher rate of recorded blood pressure readings in the first ten days postpartum compared to those randomized to an in-office blood pressure check.[15] Studies such as these are scarce, and there remains a lack of good-quality evidence on the usefulness and efficacy of RPM in patients with HDP.

Our study proposes that the use of mobile health technology, specifically a Bluetooth-enabled blood pressure cuff, will improve the care of women with hypertension in the postpartum period by increasing the amount of blood pressure data collected in the outpatient setting. Increased data and closer surveillance will allow for more active titration of anti-hypertensive medications and assessment of symptoms. We also propose that patients will feel more involved in and connected to their care using RPM.

2.2 Specific aims

Our objective is to trial RPM in the postpartum hypertensive population in a randomized control design, with an aim to increase the number of blood pressure measurements taken during the fragile and under-monitored postpartum period and to thereby improve postpartum blood pressure control and reduce severe morbidity and mortality.

Specific Aim 1. To compare the number of blood pressures recorded in the first 10 days postpartum between patients who have been enrolled in an RPM trial to those who are being treated with the usual care. We hypothesize that women using RPM will have more blood pressure values recorded at outpatient blood pressure assessment compared with patients using the usual care.

- **Sub-aim 1: To compare the percentage of elevated blood pressures that are discussed with an obstetric care provider between patients who have been enrolled in an RPM trial to those who are being treated with the usual care.** We hypothesize that women using RPM will communicate more frequently with their providers regarding elevated blood pressure values.
- **Sub-aim 2: To examine the effect of RPM on blood pressure control at 6 weeks in women with HDP.** We hypothesize that more women using RPM will be normotensive, defined as blood pressure < 140/90 mm Hg, at the end of the postpartum period, compared to those randomized to usual care.
  Sub-aim 3: To compare time to outpatient initiation or adjustment of antihypertensive medications in women using RPM compared to the usual care. We hypothesize that women using RPM will have shorter time to initiation of medications or shorter time to change in medication regimen in the outpatient setting than those using the usual care.

Specific Aim 2. To compare rates of compliance with follow up visits between patients who have been enrolled in an RPM trial to those who are being treated with the usual care. We hypothesize that women using RPM will have a higher rate of compliance with outpatient blood pressure assessments and postpartum visits than patients using the usual care

- **Sub-aim 1: To analyze factors associated with poor postpartum follow up in both the study group and the control group.** We hypothesize that factors such as socioeconomic status, wait times at the office or clinic where care is provided, number of children at home, and educational level will be associated with lower follow-up rates.

Specific Aim 3. To assess the ease of use and satisfaction for RPM. We hypothesize that women who use RPM will be satisfied with this method of blood pressure monitoring, and will

feel overall more connected to their care and to their providers than women who receive the usual care.

2.3. Methods

2.3.1 Study Design

This will be a randomized control trial, in which women with HDP diagnosed prior to delivery will be assigned to either usual care or to a telehealth kit that, supplied by Philips. New York Presbyterian has a contract in place with Philips (attached separately to this IRB application under "Philips Contract 5.30") which allows the hospital to utilize Philips telehealth programs for its patients. The telehealth kit will include a Bluetooth-enabled blood pressure cuff which is FDA approved to monitor blood pressure as well as pulse, and a tablet that includes a clinical monitoring software (eCareCoordinator, or eCC). Further details regarding the devices are outlined in the "Equipment and Software" section below.

Patients will be recruited from the postpartum service. All patients will be asked to check their blood pressure twice per day, once in the morning and once in the evening. Pulse will also be recorded as it is taken automatically at time of blood pressure reading; though this parameter is not being studied, there will be protocols in place to address abnormal values. Control group patients will use the blood pressure cuff that they procure after discharge using the prescription they are given, and will be asked to keep a log of their blood pressure measurements. Study group patients will use the Philips Bluetooth-enabled blood pressure cuff, which will transmit blood pressure measurements via Bluetooth from the monitor to the eCC. These patients will be educated on the use of and enrolled in the software by Philips representatives (via telephone) and research investigators who have been in-serviced on the devices prior to discharge. The tablets are cellular-enabled, so no wireless connection is needed in the patient's home.

Measurements and surveys for patients in the study group will be scheduled in the eCC (see "HDP Calendar and Intervention Rules," attached as a separate document to this IRB application). Data for patients in the study group will be transmitted to the Philips Clinical Call Center, staffed daily by nurses from 8am-8pm. The nurses will review measurements and survey results within 2 hours when they are flagged as high for attention. Criteria for flagging and therefore review by a nurse as well as for escalation to an obstetric provider is outlined in the workflow attached as separate documents to this IRB ("HDP calendar and intervention rules" / "Workflows"). If a measurement is flagged as high, the nurse will contact the patient and the patient's provider (if the patient has not) by phone. The patient will also be automatically instructed via the system to call their provider immediately. If a measurement is flagged as low, the nurse will email the patient's provider with a summary of the day's measurements at the end of the day. If a patient does not enter measurements, the nurse will contact the patient directly. If the patient does not enter measurements for 3 consecutive days, the nurse will contact the patient's provider, and will continue attempting to contact the patient daily. If a nurse cannot get in touch with the patient, the nurse will contact the patient's provider. If a survey answer is flagged, the nurse will contact the patient and the patient's provider (if the patient has not) by phone. The patient will also be automatically instructed via the system to call their provider immediately. If the patient does not answer a survey, the nurse will contact the patient the

following day. For all patients, regardless of whether or not they have flagged values, a weekly report of measurements will be generated and sent to the patient's providers every week.

Patients in both groups will be given an appointment to follow-up with their obstetric provider in the office at 7-10 days postpartum. Control group patients will be asked to bring a log of their recorded blood pressures to this visit. The number of measurements *total* and the number of measurements that were *elevated* will be ascertained for each group at this visit.

Patients in the study group will also be prompted to answer a daily survey within the Philips application regarding symptoms of preeclampsia, a weekly survey regarding their medications and satisfaction surveys prior to and at the conclusion of the study period. Patients in the control group will also be given satisfaction surveys prior to and at the conclusion of the study period.

Patients in both groups will be followed from recruitment until the date of their postpartum visit.

Flowcharts illustrating the above work flows can be found in separate attachments to this IRB application ("HDP calendar and intervention rules" / "Workflows").

2.3.2 Inclusion Criteria

Women who meet the following criteria will be eligible for the study:

1) Postpartum women
2) Antepartum diagnosis of hypertension, defined as existing chronic hypertension diagnosis or documented blood pressure of ≥140 systolic OR ≥90 diastolic on at least 2 occasions at least 4 hours apart prior to delivery
3) At least 18 years of age
4) English or Spanish speakers

2.3.3 Exclusion Criteria

1) Non-English or Spanish speakers
    - The consent form will only be available in these 2 languages
2) Lives outside of NY State, unless their physician is licensed in the state of residence
    - The telemedicine laws in NJ prohibit physicians from practicing telemedicine unless licensed in NJ; the NYP legal team is investigating if this is true for other states
3) Women who are not planning on obtaining their postpartum follow up at CUIMC
4) Women who are physically unable to hold or use the tablet
5) Women who do not have a working phone
6) Women whose obstetric providers are unable or unwilling to implement escalation pathways
7) Women who were diagnosed with hypertension postpartum

2.3.4 Recruitment, Screening and Enrollment

We will use a recruitment strategy designed and utilized by the OB department. An OB research coordinator (RC) will perform daily chart screen of all women admitted to the CUIMC postpartum unit (CHONY 5 central, 6 central and 10 central). Permission from healthcare providers will be obtained prior to the OB RC contacting participants. Eligible women will then be recruited from the aforementioned postpartum units. After obtaining written informed

consent, participants' sociodemographic characteristics will be collected. Information regarding their diagnosis of HDP and delivery information will be collected at that time as well. They will then be randomized to either usual care, as defined above, or the study group. Randomization will occur in REDCap. Those in the study group will be educated on use of the Philips equipment by research personnel who will have been educated on use of the equipment, with support over the phone by a Philips representative. Nursing staff will be familiarized with the equipment as well, and will be available to answer any questions the patient might have. Patients in the study group will be provided with the Philips telehealth kit, complimentary of participating in the study, prior to being discharged from the hospital (see "Equipment and Software" section, below). Their chart will be created in the eCC prior to discharge from the hospital by the RC.

Once home, the patient will receive a "Welcome Call" from a Philips representative, which will ensure that the equipment is set up properly and that all the patient's questions are answered. If the patient has any remaining difficulty with equipment, Philips will arrange for a home visit from a representative, which will occur within 72 hours. Prior to that visit, if the Bluetooth system is not working properly, the cuff will still work as a normal blood pressure cuff, so the patient will be able to take measurements.

2.3.5 Equipment and Software

The usual care group will be given a prescription for a blood pressure cuff. In general, the prescription does not specify a model of cuff; this is up to the discretion of the pharmacist or the patient.

The study group will receive a Philips Home Telehealth Solution kit, complimentary of participating in the study, which includes several FDA/FCC approved devices. NewYork-Presbyterian has a contract in place with Philips (attached separately to this IRB application under "Philips Contract 5.30") which allows the hospital to utilize Philips telehealth programs for its patients. **The investigators had no role in the signing of this contract and have no financial interests in this program.** The following equipment is included in the Philips kit:

Device	US 510(k)
A&D Blood Pressure Meter, regular or small cuff version UA-767PBT-Ci	Class II K043217 FCC:POOWML-C40
eCareCoordinator (eCC) Suite	K171029
Samsung Galaxy Tab E 8.0" model SM-T377A	Not a medical device, no associated 510(k) FCC: A3LSMT377A

The instructions that patients will receive for use of the tablet and the blood pressure meter are attached separately to this IRB application ("Philips patient instructions"/ "A&D Cuff Instructions").

The eCC Clinical User Guide is also attached separately to this IRB application ("eCC Clinical User Guide for Version 1.6"). It outlines the use of the applications contained within the eCC Suite for both patients and providers, including the metrics that can be collected for each patient.

The most relevant components of this document are listed below. The page numbers listed refer to the page number within the PDF document and not the page number found in the bottom right corner of each page.

- Patients view (p.24-25): describes the columns of information that are available for review and analysis
- Overall score/flag values (p.27-29): describes how clinical data is flagged for review
- Hospital admissions/ED visits (p.73-76): describes how hospital admissions and ED visits are tracked within the patient chart.
- Calendar (p.79-80): illustrates the patient tasks expected each day in a calendar format. These tasks may include surveys, measurements, clinician tasks, appointments and sticky notes.
- Surveys (p.86-89): describes how surveys are displayed as part of the calendar and how they can be accessed. The surveys that will be available as part of this study are attached as a separate document to this IRB application ("Surveys"). They include:
    - Preeclampsia Symptom Survey-scheduled
    - Preeclampsia Symptoms Survey-reflexive, high acuity
    - Preeclampsia Symptoms Survey-reflexive, low acuity
    - Medication Survey
    - Satisfaction Survey-Program Start (*will also be given to the control group*)
    - Satisfaction Survey-Program End (*will also be given to the control group*)
    - Telemedicine Survey Specific-Program End
- Measurements (p.91-92): describes how patient measurements are displayed and scheduled. **For this study, only blood pressure and heart rate will be measured.**
- Patient issues (p.128-137): describes how acute conditions that affect daily patient care activities are monitored and how chronic problems are tracked.
- Reviewing flags and issues (p.142-146): describes how patients are flagged for clinical assessment and intervention, and how these flags and issues are reviewed and addressed
- Intervention rules (p.188- 210): conditional statements that consist of a condition and an action that the system will trigger when the condition is met. **The intervention rules for this study are attached to the IRB application as a separate document ("HDP calendar and intervention rules") and workflows can be found as a separate document as well ("Workflows").**

At the conclusion of the 6-week study period (in other words, after the scheduled postpartum visit or the time when that visit was supposed to occur, if the patient did not present), the patient

will be expected to return the kit. The full patient terms of use are attached to this IRB application as a separate document ("Philips Terms of Use").

2.3.6 Outcomes

1) **Primary outcome:** Our primary outcome will be percentage of the recommended twice daily blood pressures reported between hospital discharge and outpatient blood pressure assessment.
2) **Secondary outcomes:** Secondary outcomes will include:
    1. Percentage of recorded blood pressure values during that time frame that are elevated (>140 systolic OR >90 diastolic)
    2. Percentage of elevated blood pressures that triggered a phone call to an obstetric provider
    3. Rate of attendance at outpatient blood pressure assessment
    4. Incidence of elevated blood pressure at the outpatient blood pressure assessment
    5. Rate of outpatient assessment for postpartum care
    6. Incidence of elevated blood pressure at the postpartum assessment
    7. Time to initiation of antihypertensive medications (in patients who were not on medications at time of discharge) and adjustment of antihypertensive medications
    8. Final dosage of antihypertensive medications at 6 weeks postpartum
    9. Readmission rate
    10. Rate of emergency department visits
    11. Rate of HDP-associated morbidities (e.g.: stroke, seizure, PRES)
    12. Percentage of patients who require a referral to primary care physicians after being discharged from obstetric care at the postpartum visit
    13. Patient satisfaction with the method, to be assessed via a validated clinical survey (attached separately in the document entitled "Surveys").

2.3.7 Measures

The following data will be collected for analysis.

1) **To be collected on enrollment/prior to hospital discharge:**
    1. **Demographic and social factors.** Date of birth, self-reported race/ethnicity, cultural background [place of birth (US or not), years living in the US, and primary language spoken in the home, marital status, highest level of maternal education attained, employment status, household income, insurance status and city of residence/zip code will be elicited from the patients on enrollment
    2. **Pregnancy history.** On enrollment, participants will be asked about the number and outcomes of prior pregnancies
    3. **Prenatal care history.** Location of prenatal care, GA on initiation of prenatal care and number of prenatal visits will be extracted from the EHR when possible and verified by the participant on enrollment.

4. **Delivery history.** Mode of delivery and baby's disposition will be collected on enrollment
5. **Medical history**. Other medical history will be extracted from the EHR and verified by the participant on enrollment
6. **Health behaviors.** Current and prior smoking, alcohol, and illicit drug use will be elicited on enrollment.
7. **Weight and height.** Height, pre-pregnancy weight, first documented weight during the pregnancy, and weight at enrollment, will be obtained on enrollment and extracted from the EHR. Body mass index (BMI) will be calculated as height (cm)/weight (kg)2.
8. **Blood Pressure.** Blood pressure history, including time of diagnosis of hypertensive disorder, precise HDP diagnosis and exposure to magnesium sulfate or antihypertensive medications will be ascertained on enrollment and verified prior to discharge.
9. **Hospital length of stay.** defined as days AFTER delivery that the patient is admitted to the hospital; this will be ascertained upon hospital discharge
10. **Medications.** discharge antihypertensive medications will be collected upon discharge

2) To be collected throughout the study period:

1. **Blood pressures.** For the control group, participants will be asked to provide a record of the blood pressures they are recording at home, and the blood pressures from their office visits will be recorded as well. For the study group, participant blood pressures will be stored in eCC, and the blood pressures from any in-person visits will be recorded as well. Percentage of scheduled blood pressure readings that are recorded will be compared between groups. Incidence of elevated blood pressures during this time will also be compared between groups.
2. **Communication.** Rate of communication between patient and obstetric provider for each abnormal blood pressure measurement will be compared between groups.
3. **Adherence.** For both groups, rate of presentation for scheduled appointments will be collected. For the study group, eCC will collect patient reports of reasons why they were unable to check their blood pressure or attend a scheduled appointment
4. **Time to initiation of medications.** For both groups, time to initiation of anti-hypertensive medications will be tracked
5. **Final plan at 6 weeks.** For both groups, continuing medication regimens at 6 weeks will be collected. Referral to primary care physician will be collected.
6. **Hospital readmissions.** Hospital readmission for any indication will be collected for both groups
7. **ED visits.** Presentation to the emergency department for any indication will be collected for both groups
8. **Maternal morbidity and mortality.** Incidences of eclampsia, stroke, PRES, maternal death and other preeclampsia-associated morbidities will be collected for both groups
9. **Home Health Services:** information regarding the use of home health services after discharge including referral to home health services, number of visits and blood pressure at those visits will be collected for both groups

2.3.8 Definitions

Chronic hypertension will be defined according to ACOG guidelines as blood pressure measurement of EITHER ≥140 mm Hg OR diastolic ≥90 mm Hg on at least 2 occasions, at least 4 hours apart, prior to 20 weeks gestation [1]

Hypertensive disorders of pregnancy will be defined according to ACOG guidelines.[1] The minimum criteria for a diagnosis of HDP are as follows:

- Blood pressure measurement of EITHER systolic ≥140 mm Hg OR diastolic ≥90 mm Hg on at least 2 occasions, at least 4 hours apart, between 20 weeks gestation and delivery
- Blood pressure measurement of EITHER systolic ≥160 mm Hg OR diastolic ≥110 mm Hg on at least 2 occasions qualifies as severe features

The following investigations are routinely undertaken in the clinical setting once HDP is identified in order to further categorize HDP into more specific diagnoses. These results will be reviewed for each patient to ensure the correct diagnosis has been assigned to the patient. Blood pressure findings as above with none of the findings listed in the table below satisfies a diagnosis of gestational hypertension.

Type of test	Cutoffs	Diagnosis
Urine	-24-hour protein concentration > 300 mg OR -Protein/Creatinine ratio > 0.3	Preeclampsia
Serum	-Platelets <100,000/microliter OR -Creatinine >1.1 mg/dL, or doubling from baseline OR -LFTs > twice the upper limit of normal concentration or twice baseline	Preeclampsia with severe features
Signs/symptoms: any of the following, if not accounted for by another diagnosis	-New-onset, refractory cerebral or visual disturbances -Severe persistent right upper quadrant or epigastric pain unresponsive to medication -Pulmonary edema -Blood pressure ≥ 160 systolic OR ≥110 diastolic	Preeclampsia with severe features
Serum	-Platelets <100,000/microliter AND -Evidence of hemolysis	Hemolysis, elevated liver enzymes and low platelet count (HELLP) syndrome

	AND -LFTs > twice the upper limit of normal concentration or twice baseline	
Signs/symptoms	New-onset, grand mal seizure, with no history of seizure disorder and not accounted for by any other diagnosis	Eclampsia

2.4 Statistical Analyses

2.4.1 Sample size and statistical power

Though data on the rate of follow up in patients with HDP are scarce, we will presume that the percentage of patients who record their blood pressures accurately postpartum is similar to the rate noted in the few studies that have measured similar metrics, approximately 43.7%.[15] We currently have IRB approval for a retrospective study to assess the postpartum follow up of women with HDP over the past 2 years at CUIMC (protocol AAAR9887). Until data collection for this study is complete, we will not precisely know the baseline rate of compliance with blood pressure measurements in the first 7-10 days postpartum. Therefore, in order to err on the side of making sure we are well powered, we will use 60% as an estimated percentage of twice daily blood pressures that are recorded in the usual care group. Aiming to achieve a rate of 80% for twice daily blood pressure recordings in the study group with 80% power, we would need to recruit 81 patients to each group. Allowing for the possibility of loss to follow-up and to compensate for the reduced power due to statistical adjustment for potential confounders, we inflated the sample size by 25%. 101 patients will therefore need to be recruited to each group, or 202 patients total. The randomization sequence was built based on an overestimate of dropout rate. Therefore, we increased our target enrollment from 202 to 220. Once the sample size is reached, enrollment will stop.

2.4.2 Statistical analysis

For analysis of discrete (categorical) data in independent samples, the Chi-squared test or Fisher exact probability test will be utilized. For group comparisons, continuous data that satisfy the assumptions of normality and homoscedasticity (homogeneity of variance) will be analyzed by t-test (for 2 independent samples) or analysis of variance (>2 groups, ANOVA) with post hoc comparisons by Scheffe tests. When possible, continuous data that do not fulfill the aforementioned assumptions will be mathematically transformed (e.g., logarithmic transformation) before performing t-tests or ANOVA. In some cases, data that do not satisfy these assumptions will be analyzed by nonparametric methods [Mann-Whitney U Test (for two independent samples) or Kruskal-Wallis One-Way ANOVA (for more than two independent

samples)]. Significant Kruskal-Wallis ANOVAs will be followed by Dunn tests for post hoc analysis. The degree of linear association between variables will be measured by the Pearson product moment correlation coefficient or the Spearman rank-order correlation coefficient and their corresponding tests of significance. Multivariate linear or logistic regression will be utilized where appropriate. In all cases, statistical significance will be assumed when $p<0.05$. Propensity score analysis will be used as a balancing score as deemed necessary.

2.4.3 Strengths and limitations

Strengths of our study include a randomized control design, as well as a large cohort of patients who will be eligible for enrollment. CUIMC has 9 obstetric clinics which annually experience 27,612 deliveries, of which 2,853 (approximately 160/month) are affected by HDP. An additional strength of our study is that the Philips RPM system has been previously tested in pilot studies at other institutions and is currently being trialed in a 30-day pilot program in the Emergency Department at CUIMC, projected to end in mid-October 2018, prior to the projected start of this study. If there are any unforeseen issues with equipment or installment, these will be able to be resolved prior to the rollout of our study.

Project limitations include potential fear among patients of a new technology that could limit enrollment. Additionally, patients may not present to their 7-10 day postpartum blood pressure check, which would limit the results; however, we did try to account for this when calculating our sample size. Finally, a limitation of the study is that control patients may be more cognizant of checking their blood pressures due to being enrolled in a research protocol, and this may falsely inflate their blood pressure recording rates. However, even if the control group has higher compliance with blood pressure measurements than the baseline population, we still anticipate that the study group will have a statistically significant increase in these measurements.

2.5. Anticipated outcomes

The primary outcome will be the difference in the percentage of twice-daily blood pressures reported between hospital discharge and the outpatient blood pressure assessment. We anticipate that the patients enrolled to RPM will have a significantly higher percentage of blood pressures recorded. Thus, there will be more data, available at an earlier time point in the postpartum period, which providers can use to make decisions regarding titrating medications and need for closer monitoring. We anticipate that patients enrolled in RPM will have more communication with their obstetric providers, higher compliance with their scheduled postpartum visits, and better blood pressure control at 6 weeks postpartum. We also anticipate that these patients will feel like they have had a more active role in their own care, and will feel more connected to their providers during the fragile and currently under-monitored postpartum period.

2.6. Significance

There are several knowledge gaps in the postpartum management of women with HDP. The short term postpartum course of BP in women with HDP and time to normalization of BP in women with HDP have not been well described. Clinical characteristics associated with the

duration of postpartum HTN and the adherence to and tolerability of RPM in the postpartum state are unknown. These knowledge gaps have important clinical implications and answering them will provide valuable information regarding the feasibility of out-of-office BP monitoring in order to care for women with HDP, who have been shown to have extremely low rates of follow-up and adherence to care. The overall goal of this project is to collect empiric data for future guidelines on the optimal use of RPM among postpartum women with HDP.

2.7 Timeline

Enrollment is planned to begin in early November of 2018, as soon as IRB approval is granted and the pilot program is complete in the Emergency Department (currently ongoing and projected to end mid-October 2018). This pilot program aims to trial the use of the Philips RPM system with Emergency Department patients, to ensure feasibility of use. We plan to recruit patients from the postpartum service after delivery. The sample size required is 101 patients per group. We anticipate that these patients will be successfully recruited into the study within a 6-month period, ending approximately in April to May of 2019. These patients will need to be followed until 6 weeks postpartum. We anticipate that the study will be completed by July 2019.

2.8. Environment

The Columbia Department of OB/GYN brings substantial experience and skill in organizing and participating in clinical research. We have a strong track record in all areas of collaborative research including protocol design, implementation, data analysis and dissemination of findings. Our productivity is facilitated by a number of factors: (1) A critical mass of academic full time faculty with sufficient time and skill to perform clinical research, (2) the presence of a diverse patient population willing to participate in research initiatives, and (3) an established research environment in which clinicians accept participation in research initiatives as a major role of a teaching institution. This has led to a longstanding reputation for excellence in clinical research.

Of utmost importance is our research infrastructure with a proven record of success, which is embedded in the elaborate system of prenatal clinics and obstetric services and complemented by our large and diverse population of over 6,600 deliveries per year, advanced support systems, strong division of Neonatology, outstanding follow-up programs and a patient population proven to be receptive to participation in research. The research staff is trained and certified in Good Clinical Practice, HIPPA, Blood Borne Pathogen Handling, and IATA Shipping Regulations. All staff is capable of collecting patient samples, cord blood and placental processing (including RNA, proteomics and DNA). Our research staff of over 25 individuals are trained and certified in each ongoing project. This maximizes efficiencies in recruitment and the performance of study procedures and also allows staff to share the responsibility of on-call coverage.

The Department of OB/GYN maintains a centralized administrative research office that manages pre- and post-award grant administration, and oversees roughly $10 million in sponsored research funding annually. The Office analyzes, monitors, and evaluates the Department's research activities including all federal and non-federal sponsored awards and contracts. They

ensure the efficient, cost-effective administration and financial management and ensure compliance with internal and external policies and procedures.

2.9. Investigators

We are uniquely qualified to perform this project, as we are in a large medical center, with a diverse patient population. Our research study will take place at Columbia University, a large academic center actively involved in a myriad of academic studies. The principal investigator, Dr. Leslie Moroz, completed fellowships in both Maternal-Fetal Medicine and Critical Care Medicine. She is the director of the Mothers Center, which provides comprehensive, multidisciplinary care for pregnant women with medical or surgical complications. She has a particular interest in developing programs that can safely provide remote postpartum care, to ease the burden of care while increasing the amount of monitoring during this critical period. She is also a dedicated teacher and mentor in the residency and Maternal-Fetal Medicine fellowship program at Columbia University. Dr. Jessica Spiegelman, a fellow in Maternal-Fetal Medicine, began her research early on in her career as an undergraduate student, and established her interest in clinical outcomes research in the community, as reflected in her peer reviewed publications. Her interest and commitment to the field of obstetrics and Maternal-Fetal Medicine continued on residency, where she established presence in the high risk obstetrics community as a contributor to research and to caring for patients in under-served populations.

Additionally, expertise for this research project includes an experienced, interdisciplinary team. Dr. Natalie Bello, who is a board-certified cardiologist with special interest in pregnant women, is the PI of a K23 grant investigating the use of home blood pressure monitoring and novel methods of clinic BP measurement in pregnant women with HTN. She is also

involved in the conduct and examination of epidemiological studies designed to elucidate the relationship between HDP and CV disease, including the California Teachers Study and nuMom2b Heart Health Study (HHS) (clinicaltrials.gov NCT02231398). Her short- and long-term career goals include the design and conduct of clinical trials to evaluate BP measurement, monitoring, and treatment during pregnancy and in the postpartum period to improve maternalfetal outcomes.

Support for database construction and management will primarily come from Cynthia Masson, Director of Clinical Information System Design and Innovation and head of the Columbia University's Department of Obstetrics and Gynecology Interdepartmental CORE Data Team. She has assisted multiple single and multi-center funded and unfunded studies in obtaining and capturing research, clinical and operational data and providing a stream-lined process for building complex databases and translating complex data for seamless data analysis.

As part of a major academic research center, we additionally have the continued support of medical students, residents and experienced research assistants.

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