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Pregnancy outcomes following home blood pressure monitoring in gestational hypertension

Erkan Kalafat[a,b], Karin Leslie[b,c], Amar Bhide[b,c], Basky Thilaganathan[b,c], Asma Khalil[b,c,*]

[a] Fetal Medicine Unit, St. George's University Hospitals NHS Foundation Trust, London, UK
[b] Middle East Technical University, Department of Statistics, Ankara, Turkey
[c] Molecular & Clinical Sciences Research Institute, St. George's University of London, London, UK

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ABSTRACT

Objectives: To assess the safety and efficacy of home blood pressure monitoring (HBPM) and office (traditional) blood pressure measurements in a cohort of pregnant women with gestational hypertension (GH).
Study design: This was a cohort study at St. George's Hospital, University of London conducted between December 2013 and August 2018. The inclusion criteria was pregnant women with a diagnosis of GH. Eligible patients were counseled and trained by a specialist midwife and were provided with an automated Microlife® "WatchBP Home" BP machine. Each patient followed an individualised schedule of hospital visits and BP measurements based on the HBPM pathway or standard hospital protocol which was based on the National Institute of Health and Care Excellence (NICE) guideline.
Main outcome measures: Adverse fetal, neonatal and maternal outcomes as well as number of antenatal hospital visits were recorded and compared between HBPM and office (traditional) pathways.
Results: 143 women with GH were included in the study (80 HBPM vs 63 standard care). There were no significant difference between the two groups in maternal high-dependency unit admission (P = 0.999), birth weight centile (P = 0.803), fetal growth restriction (p = 0.999), neonatal intensive care unit admissions (p = 0.507) and composite neonatal (p = 0.654), maternal (p = 0.999) or fetal adverse outcomes (p = 0.999). The number of Day Assessment Unit (DAU) visits was significantly lower in the HBPM group than the traditional pathway (median 4.0 vs. 5.0, P = 0.009). The difference was greater when the number of visits were adjusted for the duration of monitoring in weeks (median: 1.0 vs 1.5, P < 0.001). There were no significant difference between the two groups in the total number of outpatient (P = 0.357) and triage visits (p = 0.237). However, the total number of antenatal visits adjusted for the duration of monitoring was significantly lower for the HBPM group compared to the traditional pathway (median 1.4 vs 1.8, P = 0.020).
Conclusions: HBPM in women with GH results in significantly less antenatal visits compared to women on a standard pathway of care. The two groups had comparable fetal, neonatal and maternal adverse outcomes. Large multicentre studies are needed to ascertain the safety of rare adverse pregnancy outcomes.

1. Introduction

Hypertensive disorders of pregnancy (HDP) remain a major cause of morbidity and mortality in pregnancy worldwide [1]. Recent evidence suggests there has been a sustained reduction in maternal mortality in the United Kingdom largely as a consequence of effective management and timely intervention [2]. However, HDP remain a significant resource burden on the healthcare system due to intensive antenatal follow-up requirements for the pregnant women at risk for hypertension as recommended by NICE guidelines [3]. Women deemed to be at high risk for HDP are required to attend the maternity day assessment unit (DAU) or their community care center at regular intervals for blood pressure (BP) measurements.

Home blood pressure monitoring (HBPM) of women at high risk or with a diagnosis of HDP has been proposed as a safe alternative to standard care [4]. HBPM is a safe and a recommended tool in the

Abbreviations: HDP, Hypertensive disorders of pregnancy; HBPM, Home blood pressure monitoring; NICE, National Institute of Health and Care Excellence; BP, Blood pressure; GH, Gestational hypertension; ISSHP, International Society for the Study of Hypertension in Pregnancy; DAU, Daily assessment unit; FGR, Fetal growth restriction; SGA, Small for gestational age

* Corresponding author at: St. George's University of London, London SW17 0RE, UK.
E-mail address: akhalil@sgul.ac.uk (A. Khalil).

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management of chronic hypertension in adults, but the safety profile of HBPM during pregnancy is less well established [5]. We have previously reported that HBPM is acceptable to women and effective in reducing the number of hospital visits without compromising maternal and perinatal outcomes [4,6]. A health economic analysis suggests that the reduced burden of hospital attendance could lead to cost savings [7].

HDP includes gestational hypertension, pre-eclampsia and pre-pregnancy hypertension. Previous studies of HBPM in pregnancy included women with various types of HDP or at high-risk of developing HDP [4]. The heterogeneity of the study cohort has been highlighted as a limitation as it can impact on the reported pregnancy outcomes. The natural history of pre-existing hypertension differs from that of gestational hypertension [8,9]. Therefore, the aim of this study was to investigate the pregnancy outcomes of HBPM in a cohort of pregnant women with GH.

2. Methods

2.1. Study population

This was a cohort study at St. George's Hospital, University of London conducted between December 2017 and August 2018. The inclusion criteria was having an initial diagnosis of GH according to the International Society for the Study of Hypertension in Pregnancy (ISSHP) criteria [10]. Women presented via referral to the hypertension clinic or the DAU. Those who satisfied the inclusion criteria were invited to participate in the HBPM pathway. The exclusion criteria were diagnosis of chronic hypertension, maternal age less than 16 years, systolic BP above 155 mmHg, diastolic BP above 100 mmHg, significant proteinuria ($\geq 2+$ on dipstick testing or protein/creatinine ratio > 30 mg/mmol), an estimated fetal weight below the 10th centile, signs of severe preeclampsia (oliguria < 500 mL/24 h, cerebral or visual disturbance, pulmonary edema, epigastric or right-upper quadrant pain, impaired liver function, platelet count $< 100{,}000/mm^3$), significant mental health concerns or insufficient understanding of the English language. The pregnancy outcomes and number of hospital visits of women with GH who had HBPM were compared with those of another group of pregnant women with GH, but were managed via the traditional pathway (hospital BP monitoring), as per the National Institute of Health and Care Excellence (NICE) guideline [3]. The latter group was derived retrospectively from maternity databases and consisted of a historic cohort of women who presented to the DAU with GH and were managed as per the local hospital protocol prior to the implementation of HBPM.

Eligible patients for the HBPM pathway were counseled and trained by a specialist midwife and were provided with an automated Microlife® "WatchBP Home" BP machine which is validated for use in pregnancy. The same BP device was used to record their BP at the hospital. Women were taught how to measure their BP accurately according to our previously published technique: appropriate size arm cuff, taken at rest after 5 min, sitting with the back supported and the feet flat on the floor, keeping the arm at the level of heart and removing tight or excessive layers of clothing and avoiding excessive consumption of stimulant drinks (i.e. coffee). Women recorded readings in their notes or on a specially designed smartphone app (Hampton Medical®, Trakka Medical, UK, Downloadable at https://itunes.apple.com/us/app/hampton-medical/id1328312740?mt=8). Each patient followed an individualised schedule of hospital visits and BP measurements based on the HBPM pathway or standard hospital protocol, which was based on the NICE guideline [3]. Patients were given written instructions regarding when to present to hospital based on their HBPM readings being out of normal range or on their reporting symptoms of preeclampsia. Our protocol used a systolic blood pressure of > 155 mmHg or a diastolic blood pressure of > 100 mmHg as the trigger for a patient to contact the hospital for review, to avoid patients developing severe hypertension at home.

Data on maternal age, parity, self-reported ethnicity, mode of conception, smoking status, type of HDP at delivery, adverse fetal, neonatal and maternal outcomes were recorded. Adverse fetal outcome was defined as preterm delivery prior to 34 weeks' gestation, birth weight centile below the 3rd or intrauterine demise. Fetal growth restriction (FGR) and small-for-gestational age (SGA) diagnoses were made according to the Delphi consensus criteria by Gordjin et al. [11]. Adverse maternal outcome included acute renal failure (maternal serum creatinine level above 100 μmol/L antenatally or above 130 μmol/L postnatally) or need for dialysis, acute myocardial ischemia, need for third intravenous agent to control BP (i.e. in addition to labetalol and hydralazine), hypertensive encephalopathy (altered mental status with characteristic cerebral imaging), cortical blindness, retinal detachment, stroke (ischemic or hemorrhagic), pulmonary edema or adult respiratory distress syndrome (defined by characteristic pulmonary imaging in addition to oxygen requirement), need for mechanical ventilatory support (other than for Cesarean section), disseminated intravascular coagulation, thrombotic thrombocytopenic purpura or hemolytic uremic syndrome, acute fatty liver, liver hematoma or rupture, placental abruption, and maternal death. Adverse neonatal outcome included neonatal death, respiratory distress syndrome, intraventricular hemorrhage, necrotizing enterocolitis, bronchopulmonary dysplasia, periventricular leukomalacia, retinopathy of prematurity, seizure and admission to the neonatal unit for more than 48 h (for full-term infant). Diagnoses of GH and preeclampsia were made according to the criteria of the ISSHP [8]. GH was diagnosed in the presence of systolic BP ≥ 140 mmHg and/or diastolic BP ≥ 90 mmHg at least 4 h apart in the absence of proteinuria, after 20 weeks' gestation in a previously normotensive woman. Preeclampsia was diagnosed when GH was complicated with significant proteinuria ($\geq 2+$ protein on dipstick testing or PCR ≥ 30 mg/mmol). White-coat hypertension was diagnosed when office measurements were consistently higher than home measurements which were normal. Ethical approval was obtained for the study (16/NW/0206).

2.2. Literature review

A literature review using the MEDLINE database was also undertaken in December 2018 to summarize the evidence regarding HBPM use in pregnant women. Search parameters of "home", "blood pressure", "ambulatory", "pregnancy" were used to identify relevant studies which compared BP monitoring with standard care and also reported on the pregnancy outcomes. Studies in which home blood pressure monitoring was performed with either ambulatory or automated monitors and also reported on adverse maternal or fetal outcomes were included. Validation studies were excluded. Studies characteristics and adverse outcomes were summarized in review tables.

2.3. Statistical analysis

Continuous variables were presented as medians and interquartile ranges. Binary and categorical variables were presented as fraction of the total and percentages. Distribution assumptions for continuous variables were visually assessed with quartile-quartile plots and then were confirmed with Shapiro-Wilk test. Differences between home and office BP measurements groups were tested with Wilcoxon rank sum test, *t*-test or Fisher's exact test, where appropriate. P values below 0.05 were deemed statistically significant. All statistical analyses were performed using R for Statistical Computing Software® (Version 3.4.2) [12].

Table 1
Comparison of baseline demographics and pregnancy related variables in women with gestational hypertension according to whether they had home blood-pressure monitoring or standard hospital blood pressure pathways.

	Home blood pressure monitoring (n = 80)	Standard hospital blood pressure pathway (n = 63)	P value*
Maternal age in years, median (IQR)	34.0 (30.0–37.0)	31.0 (28.0–33.5)	< 0.001
Self-reported ethnicity, n (%)			
- Caucasian	56 (70.0)	39 (61.9)	0.676
- Afrocarribean	8 (10.0)	6 (9.5)	
- Asian	10 (12.5)	12 (19.1)	
- Mixed	6 (7.5)	6 (9.5)	
Multiparous, n (%)	21 (26.3)	12 (19.1)	0.326
Body-mass index in kg/m^2, median (IQR)	26.4 (23.6–30.0)	27.1 (24.2–30.3)	0.162
Body mass index ≥ 30 kg/m^2, n (%)	21 (26.3)	18 (28.6)	0.850
Body mass index ≥ 40 kg/m^2, n (%)	2 (2.5)	4 (6.3)	0.405
Smoker, n (%)	1 (1.3)	0 (0.0)	0.999
End diagnosis, n (%)			
- Gestational hypertension	56 (70.0)	41 (65.1)	0.353
- Preeclampsia	20 (25.0)	22 (34.9)	
- Other (White-coat, normotensive)	4 (2.5)	0	
Gestational age at inclusion, median (IQR)	34.0 (28.2–36.3)	36.0 (33.0–37.3)	0.002
Gestational age at delivery, median (IQR)	38.9 (37.5–39.7)	39.4 (38.3–40.4)	0.064
Duration of monitoring in weeks, median (IQR)	4.8 (1.8–8.6)	3.6 (2.2–5.3)	0.162

†Including emergency cesareans and instrumental deliveries.
IQR: interquartile range.
* Calculated with either *t*-test, Wilcoxon rank sum test or Fisher's exact where appropriate.

3. Results

A total of 143 women with GH were included in the study. 80 women were enrolled in the HBPM pathway whereas 63 women received standard care. Women in the HBPM group were older compared to controls (median 34.0 vs. 31.0 years, respectively, P < 0.001), but no significant differences were observed regarding ethnicity (P = 0.676), parity (P = 0.326), body-mass index (P = 0.162) or smoking status (P = 0.999) (Table 1). The gestational age at inclusion was significantly lower in the HBPM group compared to controls (median: 34.0 vs. 36.0 weeks, respectively, P < 0.002). However, no significant differences were observed regarding the gestational age at delivery (P = 0.064). The incidence of preterm birth prior to 34 weeks was similar between the two groups (P = 0.582). The incidence of vaginal delivery, operative delivery and elective cesarean section were similar between the HBPM and control groups (P = 0.171) (Table 2). No significant differences were observed regarding maternal high-dependency unit admission (P = 0.999), birth weight centile (0.803), fetal growth restriction (p = 0.999), neonatal intensive care unit admissions (p = 0.507) and composite neonatal (p = 0.654), maternal (p = 0.999) or fetal adverse outcomes (p = 0.999) (Table 2).

HBPM pathway significantly reduced the number of DAU visits (median 4.0 vs. 5.0, P = 0.009) (Table 2). The difference was greater when the number of visits were adjusted for the duration of monitoring in weeks (median: 1.0 vs 1.5, P < 0.001). No difference was observed between the groups regarding the total number of outpatient (P = 0.357) and triage visits (p = 0.237). However, the total number of antenatal visits adjusted for the duration of monitoring was significantly lower for the HBPM group compared to controls (median 1.4 vs 1.8, P = 0.020) (Table 2).

3.1. Literature review

The literature search revealed 10 studies to be included in the review table [4,13–21]. Seven studies applied HBPM to women in antenatal period whereas three studies used HBPM for postpartum surveillance (Table 3). The primary outcome was feasibility or acceptance of HBPM in most studies, while two studies focused on number of antenatal visits. Overall, the inclusion criteria, type of studies, method of HBPM and reported outcomes varied significantly among those studies (Table 3). The incidence of various pregnancy outcomes were extracted from the individual studies. Some studies demonstrated a lower rate of induction of labor, NICU admission, serious maternal morbidity with HBPM (Table 4) [4,17,18]. Moreover, the postpartum visit adherence was higher in the HBPM group in two studies with postpartum follow-up [14,16].

4. Discussion

4.1. Summary of the study findings

HBPM in women with GH results in significantly less antenatal visits, per week of monitoring and total, than women on a standard pathway of care. The two groups had comparable adverse maternal and perinatal outcomes.

4.2. Strength and limitations

Our study has several strengths. Firstly, this study focused on women with GH at the initial diagnosis, and therefore, avoids the potential heterogeneity in some of the previous studies. GH is the most common form of HDP with a different outcome profile compared to other HDP [22]. This study provides more relevant individualized data for the majority of women experiencing hypertension in pregnancy. Secondly, we included a relatively large cohort of pregnancies with GH and used a measurement device validated for pregnancy. Thirdly, we summarized the published evidence on the use of HBPM in pregnancy.

We cannot exclude a possibility for intervention or selection bias in our study in view of its observational design. However, the primary outcomes (maternal, fetal, neonatal adverse events) are unlikely to be affected by this potential bias. In fact, appropriate selection of pregnant women who would be eligible for HBPM is instrumental to ensure

Table 2
Comparison of the number of antenatal visits stratified by the type of visit and pregnancy outcomes in women with gestational hypertension according to whether they had home blood-pressure monitoring or standard hospital blood pressure pathways.

	Home blood pressure monitoring (n = 80)	Control (n = 63)	P value*
Preterm delivery below 34 weeks, n (%)	1 (1.3)	2 (3.2)	0.582
Induction of labour, n (%)	37 (46.3)	39 (61.9)	0.066
Mode of delivery, n (%)			
- Vaginal delivery	35 (43.8)	28 (44.4)	0.171
- Elective cesarean	13 (16.2)	4 (6.4)	
- Operative delivery†	32 (40.0)	31 (49.2)	
High Dependency Unit admission, n (%)	6 (7.5)	4 (6.4)	0.999
Birthweight in grams, median (IQR)	3100 (2570–3602)	3200 (2885–3625)	0.247
Birthweight percentile, median (IQR)	33.4 (13.5–73.8)	33.0 (14.1–66.4)	0.803
Small-for-gestational age at birth, n (%)	19 (23.8)	11 (17.5)	0.412
Fetal growth restriction at birth, n (%)	5 (6.3)	4 (6.4)	0.999
Neonatal intensive care unit admission, n (%)	4 (5.0)	5 (7.9)	0.507
Livebirth, n (%)	80 (100.0)	63 (100.0)	0.999
Composite adverse outcomes, n (%)			
- Fetal	6 (7.5)	4 (6.4)	0.999
- Maternal	1 (1.3)	1 (1.8)	0.999
- Neonatal	2 (2.5)	3 (4.8)	0.654
- All	9 (11.3)	6 (9.5)	0.790
Day assessment unit (DAU) visits			
- Total, median (IQR)	4.0 (2.0–6.0)	5.0 (4.0–7.0)	0.009
- Per monitoring week, median (IQR)	1.0 (0.5–1.8)	1.5 (1.0–2.0)	< 0.001
Maternity Triage visits (out of hours)			
- Total, median (IQR)	0.0 (0.0–1.0)	0.0 (0.0–1.0)	0.237
- Per monitoring week, median (IQR)	0.0 (0.0–0.2)	0.0 (0.0–0.2)	0.553
Outpatient visits†			
- Total, median (IQR)	1.0 (0.0–2.0)	0.0 (0.0–2.0)	0.357
- Per monitoring week, median (IQR)	0.1 (0.0–0.5)	0.0 (0.0–0.5)	0.545
All visits			
- Total, median (IQR)	6.5 (4.0–9.0)	6.0 (5.0–8.0)	0.681
- Per monitoring week, median (IQR)	1.4 (0.8–2.4)	1.8 (1.2–2.5)	0.020

* Wilcoxon rank sum test.
† Including visits to general practitioner, Triage and outpatient antenatal clinic.

safety. Women with severe preeclampsia, systolic BP above 155 mmHg, diastolic BP above 100 mmHg, significant proteinuria, FGR, mental health disorder or insufficient understanding of the English language were not eligible for HBPM. Severe adverse outcomes such as maternal or perinatal mortality are thankfully rare in well managed GH. As such the sample size in our study cannot provide robust evidence on these outcomes with a HBPM pathway compared to standard care, and for this purpose, very large studies would be needed. Of note, in common with the literature review there were no concerning trends in adverse outcome seen. Finally, as we included a simple literature search of similar published studies, rather than a systematic review, a meta-analysis is required to formally assess the efficacy of HBPM in pregnant population.

4.3. Interpretation of study findings and comparison with existing literature

The literature on the use of HBPM in pregnant women is limited and the safety profile of HBPM is yet to be fully ascertained. Most studies reported on the pregnancy related adverse events but the reported outcomes are inconsistent among those studies [13,15,17,18,20]. Only two randomized trials were published investigating the use of HBPM during the antenatal period with one of the studies employing ambulatory monitoring instead of self measurements with automated devices [20,21]. Moreover, the inclusion criteria of observational studies on HBPM varied greatly [13,15,19]. Despite the observed heterogeneity in the published literature, a reduction in the rate of induction of labor, maternal morbidity and NICU admissions was observed in some studies [4,17,18]. A systematic review is required to infer the direction of future studies on this topic.

4.4. Clinical and research implications

Our work provides preliminary safety and feasibility data for future trials. Larger studies are needed to compare HBPM and standard care. There is a rising interest in HBPM among the clinicians and researchers, as indicated by the number of the recently published studies in 2018 compared to the previous years (Table 3). However, the published evidence is very heterogeneous and lacks statistical power to ensure safety for rare adverse pregnancy ouctomes. Despite the fact that those studies varied in the inclusion criteria, methods used for HBPM and the reported outcomes, the vast majority demonstrate a potential benefit.

Results from a recent meta-analysis suggest that there are no systematic differences between home and office measurements; however, conflicting results have also been reported [23,24]. Furthermore, the number of BP monitors which are validated for use in pregnancy is limited and studies on the safety of HBPM with validated BP monitors are scarce [4,25,26]. There is still a need for large studies on the safety profile of HBPM given the potential implications of HBPM in the management of women with HDP during both the antenatal and postpartum periods [14].

5. Conclusion

HBPM in women with GH results in significantly less antenatal visits compared to women on a standard pathway of care. Our study further expands the maternal, fetal and neonatal safety data of the use of HBPM during pregnancy. However, large multicentre studies are needed to ascertain the safety of rare adverse pregnancy outcomes.

Table 3
Characteristics of studies reporting on the home-blood pressure monitoring in pregnant women.

Study, year	Study population and size	Study type	Period	Exclusion criteria	Method of home monitoring	Primary Outcome	Auxiliary outcomes
Barton et al. 1994 [13]	Mild gestational hypertension (n = 592)	Cohort	AN	Other medical or obstetric comorbidities	Portable BP monitor with telemetry	Not stated	Antepartum hospitalization, pregnancy prolongation, maternal and perinatal outcomes (small for gestational age, preterm delivery, gestational age at delivery)
Peek et al. 1996 [18]	Women with HDP > 20 weeks' gestation	Cohort	AN	History of hypertension, renal disease, diabetes or collagen vascular disease	Ambulatory BP monitoring without telemetry	Not stated	Development of proteinuria, preterm delivery, birth weight < 10th centile, admission to NICU, cesarean delivery
Ross-McGill et al. 2000 [21]	Low risk women (n = 80)	RCT	AN	Multiple pregnancy, previous early onset PE, serious medical disease, history of late pregnancy loss	Portable BP monitor without telemetry	Number of total hospital visits	Anxiety scores, number of BP measured weeks
Fukushima et al. 2002 [15]	Women with HDP (n = 199)	Case-control	AN	Patients who remained hospitalized until delivery, BP < 160/110 mm/Hg tested at least 3 times, delivery within a week after the first test or before 20 weeks' gestation	Portable BP monitor with telemetry	Not stated	Gestational age at delivery, mean arterial BP, birthweight, duration of pregnancy after recruitment, perinatal death
Rhodes et al. 2017 [20]	Women with HDP (n = 100)	RCT	AN	Concurrent medical conditions, multiple pregnancies, a clinical BP requiring emergency medical intervention, age < 16 years	Ambulatory BP monitoring without telemetry	Feasibility	Need for antihypertensive medication, the number of antenatal clinic or day unit visits, the duration of hospital stay and induction of labour
Perry et al. 2018 [4]	Women with HDP (n = 166)	Case-control	AN	< 16 years, severe hypertension, significant proteinuria, estimated fetal weight < 10th centile, signs of severe PE, significant mental health concerns or insufficient understanding of the English language	Portable BP monitor with telemetry	Not stated	Neonatal death, respiratory distress syndrome, intraventricular hemorrhage, necrotizing enterocolitis, bronchopulmonary dysplasia, periventricular leukomalacia, retinopathy of prematurity, seizure and admission to the NICU for more than 48 h, preterm delivery, small-for-gestational age, perinatal fetal death, serious maternal morbidity or mortality
Rhoads et al. 2018 [19]	Women with PE (n = 48)	Cohort	PP	Psychiatric disorders, no phone access	Portable BP monitor with telemetry	Factors for acceptance	Perceived satisfaction, ease of use and benefits
Cairns et al. 2018 [14]	Women with GH or PE (n = 82)	RCT	PP	> 3 antihypertensive medications, self-report of hypertension prior to pregnancy, and inability to speak English	Portable BP monitor with telemetry	Feasibility	Mean arterial BP, postnatal readmission rates, safety data, side effects, and quality of life scores
Lanssens et al. 2018 [17]	Women with HDP (n = 320)	Cohort	AN	Women at gestational age of < 10 weeks, or lack of consent	Portable BP monitor with telemetry	Number of prenatal consultations	Gestational age at delivery, intended and actual mode of delivery. birth weight, Apgar scores, and NICU admissions
Hirshberg et al. 2018 [16]	Women with HDP (n = 206)	RCT	PP	Readmissions for new-onset postpartum hypertension	Portable BP monitor with telemetry	Number of patients who reported a measured BP within 10 days	Initiation of antihypertensive medication, number of additional postpartum office or emergency room visits and readmission for persistent hypertension, attendance of the 4–6 week postpartum visit, patient satisfaction with BP surveillance and future health awareness

AN: antenatal, PP: postpartum, RCT: randomized controlled trial, HDP: hypertensive disorders of pregnancy, NICU: neonatal intensive care unit, BP: blood-pressure. PE: preeclampsia, GH: gestational hypertension, CHT: chronic hypertension, HELLP: hemolysis, elevated liver enzymes and low platelet.

Table 4
Pregnancy outcomes following home blood pressure monitoring compared to standard hospital/clinic blood pressure monitoring.

Authors and years	GA at delivery in weeks	Antenatal visits	Follow-up duration	SGA (< 10th centile) n (%)	Preterm delivery (< 37 weeks) n (%)	Induction of labor	Maternal morbidity*	NICU admission	Perinatal death	PP visit adherence
Barton et al. 1994 [13]	36.7 (3.6)	–	–	34 (5.7)	156 (30.1)	–		133 (25.6)	–	–
Cairns et al. 2018 [14]	N/A postpartum	–	–	–	–	–	–	–	–	41/45 (91.1) vs. 43/46 (93.5)
Fukushima et al. 2002 [15]	35.8 (3.4) vs. 38.2 (5.4)	–	108.0 (75.0) vs. 70.0 (62.0)	–	–	–	–	–	1/19 (5.3) vs. 1/180 (1.0)	–
Hirshberg et al. 2018 [16]	N/A postpartum	–	–	–	–	–	–	–	–	71/103 (68.9) vs. 60/103 (58.3)
Lanssens et al. 2018 [17]	37.5 (2.8) vs. 36.8 (3.6)	6.93 (3.86) vs. 7.62 (3.33)	–	–	–	28/86 (32.6) vs. 100/215 (46.5)	18/86 (20.9) vs. 104/215 (48.4)	8/86 (9.3) vs. 36/215 (16.7)	–	–
Peek et al. 1996† [18]	–	–	–	13/77 (16.9) vs. 6/38 (15.8)	11/45 (24.4) vs. 6/24 (25.0)	–	20/77 (30.0) vs. 13/38 (34.2)	9/77 (11.7) vs. 6/38 (15.8)	–	–
Perry et al. 2018 [4]	39.0 [37.6–40.3] vs. 39.3 [38.0–40.6]	0.8 [0.4–1.5] vs. 1.6 [1.0–2.3]	8.1 [3.4–16.5] vs. 4.9 [3.3–9.3]	27/108 (25.0) vs.	14/58 (24.1)‡	–	22/108 (20.4) vs. 20/58 (34.5)	12/108 (11.1) vs. 11/58 (19.0)	0/108 (0.0) vs. 0/58 (0.0)	–
Rhodes et al. 2017 [20]	–	–	–	–	–	19/51 (37.3) vs. 24/49 (49.0)	–	–	–	–
Ross-McGill et al. 2000 [18]	–	4.5 (2.2) vs. 7.4 (2.2)†	–	–	–	–	–	–	–	–
Current study	38.9 [37.5–39.7] vs. 39.4 [38.3–40.4]	1.4 [0.8–2.4] vs. 1.8 [1.2–2.5]†	4.8 [1.8–8.6] vs. 3.6 [2.2–5.3]	19/80 (23.8) vs. 11/63 (17.5)	–	37/80 (46.3) vs. 39/63 (61.9)	20/80 (25.0) vs. 22/63 (34.9)	4/80 (5.0) vs. 5/63 (7.9)	0/80 (0.0) vs. 0/63 (0.0)	–

Data are presented as mean (standard deviation), median [interquartile range] or n/N (%) for continuous and categorical variables, respectively.
NA: not applicable, –: not reported, HBPM: home blood-pressure monitoring, NICU: neonatal intensive care unit, PP: postpartum.

* Development of preeclampsia and/or HELLP syndrome.

† Data from this study represents the number of pregnancy outcome cases occurring according to the home-blood pressure or day-care unit measurements.

‡ Reported as a composite outcome.

Declaration of Competing Interest

The authors report no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.preghy.2019.07.006.

References

[1] K.S. Khan, D. Wojdyla, L. Say, A.M. Gulmezoglu, P.F.A. Van Look, WHO analysis of causes of maternal death: a systematic review, Lancet 367 (2006) 1066–1074.
[2] M. Knight, M. Nair, D. Tuffnell, S. Kenyon, J. Shakespeare, P. Brocklehurst, J.J. Kurinczuk, on behalf of MBRRACE-UK (Eds.), Saving Lives, Improving Mothers' Care – Surveillance of maternal deaths in the UK 2012-14 and lessons learned to inform maternity care from the UK and Ireland Confidential Enquiries into Maternal Deaths and Morbidity 2009-14, National Perinatal Epidemiology Unit, University of Oxford, Oxford, 2016.
[3] National Institute for Health and Care Excellence. Hypertension in pregnancy: diagnosis and management (Clinical Guideline CG107). 2010 Available at: https://www.nice.org.uk/guidance/cg107.
[4] H. Perry, E. Sheehan, B. Thilaganathan, A. Khalil, Home blood-pressure monitoring in a hypertensive pregnant population, Ultrasound Obstet. Gynecol. 51 (2018) 524–530, https://doi.org/10.1002/uog.19023.
[5] R.J. McManus, J. Mant, M. Franssen, A. Nickless, C. Schwartz, J. Hodgkinson, P. Bradburn, A. Farmer, S. Grant, S.M. Greenfield, C. Heneghan, S. Jowett, U. Martin, S. Milner, M. Monahan, S. Mort, E. Ogburn, R. Perera-Salazar, S.A. Shah, L.M. Yu, L. Tarassenko, F.D.R. Hobbs, TASMINH4 Investigators, Efficacy of self-monitored blood pressure, with or without telemonitoring, for titration of antihypertensive medication (tasminh4): an unmasked randomised controlled trial, Lancet 391 (2018) 949–959, https://doi.org/10.1016/S0140-6736(18)30309-X.
[6] E. Sheehan, A. Khalil, L. Kay, Using a smartphone app to identify signs of pre-eclampsia and/or worsening blood pressure, BJM 27 (2019) 92–99.
[7] G. Xydopoulos, H. Perry, E. Sheehan, B. Thilaganathan, R. Fordham, A. Khalil, Home blood-pressure monitoring in a hypertensive pregnant population: cost minimisation study, Ultrasound Obstet. Gynecol. (2018), https://doi.org/10.1002/uog.19041.
[8] J.M. Bregand-White, M.A. Kominiarek, J.U. Hibbard, Hypertension and patterns of induced labor at term, Pregnancy Hypertens. 10 (2017) 57–63.
[9] D. Nzelu, D. Dumitrascu-Biris, P. Kay, K.H. Nicolaides, N.A. Kametas, Severe hypertension, preeclampsia and small for gestational age in women with chronic hypertension diagnosed before and during pregnancy, Pregnancy Hypertens. 14 (2018) 200–204.
[10] A.L. Tranquilli, G. Dekker, L. Magee, J. Roberts, B.M. Sibai, W. Steyn, G.G. Zeeman, M.A. Brown, The classification, diagnosis and management of the hypertensive disorders of pregnancy: a revised statement from the isshp, Pregnancy Hypertens. 4 (2014) 97–104, https://doi.org/10.1016/j.preghy.2014.02.001.
[11] S.J. Gordijn, I.M. Beune, B. Thilaganathan, A. Papageorghiou, A.A. Baschat, P.N. Baker, R.M. Silver, K. Wynia, W. Ganzevoort, Consensus definition of fetal growth restriction: a delphi procedure, Ultrasound Obstet. Gynecol. 48 (2016) 333–339.
[12] R Core Team. R: A language and environment for statistical computing. 2015, https://www.R-project.org/.
[13] J.R. Barton, G.J. Stanziano, B.M. Sibai, Monitored outpatient management of mild gestational hypertension remote from term, Am. J. Obstet. Gynecol. 170 (1994) 765–769.
[14] A.E. Cairns, K.L. Tucker, P. Leeson, L.H. Mackillop, M. Santos, C. Velardo, D. Salvi, S. Mort, J. Mollison, L. Tarassenko, R.J. McManus, S.-H. Investigators, Self-management of postnatal hypertension: the snap-ht trial, Hypertension 72 (2018) 425–432, https://doi.org/10.1161/HYPERTENSIONAHA.118.10911.
[15] T. Fukushima, M. Berumen, N. Vargas, N. Zadeh, E.H. Hon, The effects of cardiovascular dynamics monitoring in the outpatient management of pregnancy hypertension, Am. J. Obstet. Gynecol. 186 (2002) 1207–1213.
[16] A. Hirshberg, K. Downes, S. Srinivas, Comparing standard office-based follow-up with text-based remote monitoring in the management of postpartum hypertension: a randomised clinical trial, BMJ Qual. Saf. 27 (2018) 871–877.
[17] D. Lanssens, S. Vonck, V. Storms, I.M. Thijs, L. Grieten, W. Gyselaers, The impact of a remote monitoring program on the prenatal follow-up of women with gestational hypertensive disorders, Eur. J. Obstet. Gynecol. Reprod. Biol. 223 (2018) 72–78.
[18] M. Peek, A. Shennan, A. Halligan, P.C. Lambert, D.J. Taylor, M. De Swiet, Hypertension in pregnancy: which method of blood pressure measurement is most predictive of outcome? Obstet. Gynecol. 88 (1996) 1030–1033.
[19] S.J. Rhoads, C.I. Serrano, C.E. Lynch, S.T. Ounpraseuth, C.H. Gauss, N. Payakachat, C.L. Lowery, H. Eswaran, Exploring implementation of m-health monitoring in postpartum women with hypertension, Telemed. J. E. Health 23 (2017) 833–841.
[20] C.A. Rhodes, D.G. Beevers, D. Churchill, A randomized trial of ambulatory blood pressure monitoring versus clinical blood pressure measurement in the management of hypertension in pregnancy. A feasibility study, Pregnancy Hypertens. 11 (2018) 142–144.
[21] H. Ross-McGill, J. Hewison, J. Hirst, T. Dowswell, A. Holt, P. Brunskill, J.G. Thornton, Antenatal home blood pressure monitoring: a pilot randomised controlled trial, BJOG 107 (2000) 217–221.
[22] M. Umesawa, G. Kobashi, Epidemiology of hypertensive disorders in pregnancy: prevalence, risk factors, predictors and prognosis, Hypertens. Res. 40 (2017) 213–220.
[23] K.L. Tucker, C. Bankhead, J. Hodgkinson, N. Roberts, R. Stevens, C. Heneghan, É. Rey, C. Lo, M. Chandiramani, R.S. Taylor, R.A. North, A. Khalil, K. Marko, J. Waugh, M. Brown, C. Crawford, K.S. Taylor, L. Mackillop, R.J. McManus, How do home and clinic blood pressure readings compare in pregnancy?: a systematic review and individual patient data meta-analysis, Hypertension 72 (2018) 686–694, https://doi.org/10.1161/hypertensionaha.118.10917.
[24] E. Kalafat, I. Mir, H. Perry, B. Thilaganathan, A. Khalil, Is home blood-pressure monitoring in hypertensive disorders of pregnancy consistent with clinic recordings? Ultrasound Obstet. Gynecol. 52 (2018) 515–521, https://doi.org/10.1002/uog.19094.
[25] N.A. Bello, J.J. Woolley, K.L. Cleary, L. Falzon, B.S. Alpert, S. Oparil, G. Cutter, R. Wapner, P. Muntner, A.T. Tita, D. Shimbo, Accuracy of blood pressure measurement devices in pregnancy: a systematic review of validation studies, Hypertension 71 (2018) 326–335, https://doi.org/10.1161/HYPERTENSIONAHA.117.10295.
[26] K.L. Tucker, K.S. Taylor, C. Crawford, J.A. Hodgkinson, C. Bankhead, T. Carver, E. Ewers, M. Glogowska, S.M. Greenfield, L. Ingram, L. Hinton, K.S. Khan, L. Locock, L. Mackillop, C. McCourt, A.M. Pirie, R. Stevens, R.J. McManus, Blood pressure self-monitoring in pregnancy: examining feasibility in a prospective cohort study, BMC Pregnancy Childbirth 17 (2017) 442, https://doi.org/10.1186/s12884-017-1605-0.