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Comparison of clinical blood pressure measurements to measurements according to guidelines in women admitted to the maternity ward for hypertension.

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ABSTRACT

Objective: To assess the adherence to recommended guidelines on measurement of blood pressure in obstetric clinical practice and to determine the difference in blood pressure values between observed clinical measurements and measurements strictly following recommended guidelines.

Methods: We assessed blood pressure of 60 women admitted to the maternity ward for a hypertensive disorder of pregnancy in pregnancy or postpartum. Blood pressure was measured by hospital staff according to usual clinical practice, and study personnel performed the measurement in accordance with international guidelines. Groups were compared using paired sample t-test and the Mantel-Haenszel test.

Results: None of the clinical measurements fulfilled all recommended guidelines. Study systolic and diastolic readings were lower than those obtained in the usual clinical setting (systolic BP -7.0 mmHg (95% confidence interval: -9.2 to -4.8), p<0.001; diastolic BP -2.0 mmHg (95% confidence interval: -3.7 to -0.4), p=0.02). The risk of being categorized as hypertensive (≥140/90mmHg) decreased by 22% (95% confidence interval: 0.05-0.40, p=0.01) and 22/58 (38%) women shifted to a 10 mmHg category lower in systolic blood pressure along with 15/58 (26%) in diastolic blood pressure when measurements were performed by study personnel following recommended guidelines.

Conclusion: Following recommended blood pressure measurement guidelines significantly lowers blood pressure readings and the risk of being categorized as hypertensive.

Keywords: Blood pressure, Hypertension Pregnancy-Induced, Microlife, Pregnancy.

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INTRODUCTION

Blood pressure monitoring in pregnancy is a cornerstone in the diagnosis and management of hypertensive disorders of pregnancy including preeclampsia (1). According to international societies, a standard protocol is required to ensure the accuracy of assessments due to the impact of measurement errors, time variability and circadian and seasonal variation (2,3).
Following recommended guidelines, especially repeating measurements usually decreases blood pressure in non-pregnant populations (4). No previous studies have investigated if this is also true in an obstetrical population. However, hemodynamics change dramatically during pregnancy[5] and women admitted to the maternity ward due to hypertension might therefore be susceptible to even greater fluctuations than previously described in non-pregnant populations (4,6).
Clinical measurements may fail to follow recommended guidelines. This may lead to falsely elevated readings, thereby potentially resulting in misdiagnosis and unnecessary intervention (7).
We conducted an observational study of women admitted to the maternity ward for hypertension to investigate whether clinical blood pressure measurements and measurements following recommended guidelines (2,3) differ from each other.

Patients should be seated comfortably with the back supported in a quiet room resting for 3-5 minutes before measurement.
An appropriate cuff-size should be chosen and placed at the mid arm at heart level.
Arms should be bare and resting.
Feet should be flat on the floor.
Talking is not allowed during or between measurements.
Three measurements should be obtained with 1–2-minute intervals. Blood pressure should be recorded as the average of the last two readings.
The used device should be validated.

Figure 1. Guidelines for optimal blood pressure measurements.

MATERIALS AND METHODS

Eligibility and enrolment

From November to December 2019, this observational study recruited women admitted to the maternity ward of the Obstetric Department of Copenhagen University Hospital, Rigshospitalet. Women were eligible to participate if they were above 18 years, were pregnant at or after 20 weeks' gestation or had recently delivered (< 14 days postpartum) and had a suspected or confirmed hypertensive disorder of pregnancy defined as *de novo* hypertension (blood pressure ≥140/90). Exclusion criteria included use of any medication between the assessments and inability to follow all guideline requirements (e.g. contractions or bed rest due to risk of preterm birth). Each woman could contribute with only one set of blood pressure measurements.

Blood pressure measurements

After obtaining informed consent, clinical and study measurements were performed. We based the procedure of the study measurements on guidelines published by the European Society of Cardiology/European Society of Hypertension (ESC/ESH)(2) and the International Society of Hypertension (3). The guideline used in our study and recommended by both societies is shown in Figure 1. Some guideline steps were not implemented in our study in order to minimize inconvenience for the participant. They included: 1) No smoking, coffee, or exercise for 30 min, 2) Empty bladder, 3) Measurement in both arms and 4) Standing measurement to exclude orthostatic hypertension.
Study personnel discretely observed clinical blood pressure measurements obtained by hospital staff and recorded whether the following guideline steps were followed: participant seated in an upright position with back supported, feet on the ground and arms resting, talking during the procedure, arms bare and resting and performance of consecutive measurements. Trained study personnel measured the blood pressure while strictly adhering to the steps of international guidelines listed in Figure 1: the participant was sitting up with both legs uncrossed and arms supported at heart level without talking at least three to five minutes before the measurements, any clothing

covering the location of cuff placement were removed, the correct cuff size was used ensuring that the bladder encircled 75-100% of the arm. Three measurements were taken one to two minutes apart. All clinical and study measurements were made using the device "Microlife Vital Sign Alert (VSA)" which is validated for use in pregnancy, also when complicated by hypertensive disorders of pregnancy (8, 9).

Maternal characteristic	**N**	**(Range)***
Number of participants	60	
Height (cm), Median nter-	168	(164-172)
Weight (kg), Median	80	(68-86)
BMI category	**N**	**(%)**
<25	18	(30.0)
25-30	26	(43.0)
30-35	10	(16.7)
Pregnancy status	**N**	**(%)**
< 37 weeks	15	(25.0)
> 37 weeks	16	(26.7)
Postpartum†	29	(48.3)

Table 1. Maternal characteristics of participants admitted to the maternity ward for hypertension at Rigshospitalet, Denmark, November-December 2019. *Interquartile range.

Statistical analysis

The study aimed to include 60 women admitted to the maternity ward because of hypertension based on the available time and the flow of new patients admitted to the obstetric ward.

The mean and standard deviation of the systolic and diastolic blood pressure were calculated for both measurement groups. We chose to present our results as first measurement and the average of second and third to investigate the effect of consecutive measurements. We used a paired sample t-test to compare the means of systolic and diastolic blood pressures. Bland-Altman plots of the mean difference and mean blood pressure were created to illustrate the differences, and ± 5 mmHg were chosen as reference lines (10). The Pearson correlation between the mean and the mean difference in blood pressure was calculated. Blood pressure was categorized into the groups; systolic <130, 130-139, ≥140 and diastolic <80, 80-89, ≥90. We furthermore categorized blood pressures into hypertensive (diastolic ≥90 mmHg or systolic ≥140 mmHg) and normotensive (diastolic <90 mmHg and systolic <140 mmHg). We used the Mantel-Haenszel test to determine if clinical measurements were more likely to be above the hypertension threshold (>140/90) than the study measurements. We considered a value of $p< 0.050$ as significant. All analyses were performed using SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA). No power calculations were performed.

Ethical approval:

All the participants provided informed consent. The study was exempted from ethical approval by the Regional Ethical Committee of the Capital Region (H-19069563).

Recommendation	**N**	**%**
Participant seated comfortably with back supported and both feet on ground	2	3.3
Arms bare and resting	17	28.3
Absence of talking	7	11.6
Performing three measurements with 1-2 min. intervals	3	5.0
Fulfilled all criteria	0	0.0

Table 2. Number of times different steps of the guideline were followed in clinical measurements obtained in women admitted to the maternity ward for hypertension at Rigshospitalet, Denmark, November-December 2019.

RESULTS

This study included 60 women admitted for hypertension. Two women had only two study measurements taken and could not contribute to the analysis of the mean of second and third measurement. Table 1 presents the maternal characteristics of the participants. Participants were most likely to have a BMI between 25-30 (43.0%), use a medium cuff size (91.2%), and have delivered recently (48.3%). Of the women with a BMI >30, five used a large cuff size. The median time from clinical measurement to study measurement was nine minutes (range -

52 to 17 minutes). Two women had their study measurements taken before the clinical measurement. Three women did not have a recorded time interval.

None of the clinical measurements fulfilled all criteria from the guidelines. In 12 women, the measurements fulfilled all but one criterion (mostly, the positioning criterion was not met. Categorizing upright position in bed as "sitting" (Fowler's position) resulted in additional five measurements fulfilling this criterion (Table 2).

Clinical measurements were higher than study measurements, both in terms of mean difference and the number of women in higher blood pressure categories (Table 3, Table 4). Table 3 presents the mean and standard deviation of the two measurement groups. The mean difference between clinical measurements and the mean of the second and third of study measurements were for systolic blood pressure -7.0 mmHg (95% confidence interval [95% CI]: -9.2 to -4.8, p<0.001) and for diastolic blood pressure -2.0 mmHg (95% CI: -3.7 to -0.4, p=0.02). Of the three standardized measurements, the first blood pressure reading appeared to be higher than the mean of the second and third measurements (mean differences systolic -4.2 mmHg (95% CI: -5.7 to -2.7, p<0.001) and diastolic = -1.5 mmHg (95% CI: -2.6 to -0.4, p=0.006).

Table 4 lists the number of women in each blood pressure category. To ease the comparison of clinical measurements and study measurements, we excluded the two women who did not contribute to the calculation of the mean of second and third of study measurements in the following analysis. Measuring blood pressure according to the recommended guidelines (Figure 1) resulted in 19/58 women being categorized as hypertensive (blood pressure ≥140/90, Table 4) and decreased hypertensive measurements by 22% (risk difference = 0.22, 95% CI 0.05-0.4, p<0.01) compared to clinical measurements (32/58 women were categorized as hypertensive, Table 4). Furthermore, 22 out of 58 (38%) women shifted to a 10 mmHg category lower in systolic blood pressure along with 15/58 (26%) in diastolic blood pressure when measurements were performed by study personnel following the recommended guidelines (Figure 1).

Figure 2 illustrates the mean systolic (Figure 2a) and diastolic blood pressure (Figure 2b) as a function of the difference between the clinical measurement and the mean of the second and third study measurements (Bland-Altman plot). The horizontal reference lines are drawn at 5 mmHg illustrating the number of women exceeding a difference considered clinically

Statistic	Systolic blood pressure			Diastolic blood pressure		
	Clinical BP	Study – 1st BP	Study – mean of 2nd and 3rd BP †	Clinical BP	Study – 1st BP	Study – mean of 2nd and 3rd BP †
N	60	60	58	60	60	58
Mean	136.3	133.5	129.3	87.3	86.8	85.3
± SD	10.2	9.3	9.5	7.7	7.6	6.7
Mean difference	Ref	-2.8	-7.0	Ref	-0.4	-2.0
(95% CI)		(-4.6 to -0.9)	(-9.2 to -4.8)		(-2.1 to 1.3)	(-3.7 to -0.4)
P-value‡	Ref	p=0.005	p<0.001	Ref	p=0.6	p=0.02

Table 3. Blood pressure differences between study and clinical measurements in women admitted to the maternity ward for hypertension, Rigshospitalet, Denmark, November-December 2019. SD: Standard deviation; CI: Confidence interval.

† N=58; two participants did not complete all three study measurements and were excluded from the analysis. ‡ Paired sample t-test for difference between study measurement and clinical measurement

Blood pressure category	Clinical measurements		Study 1st measurement		Study mean of 2nd and 3rd measurement†‡	
	N = 60	%	N = 60	%	N = 58	%
Systolic blood pressure (mmHg)						
<130	20	33.3	16	26.7	30	51.7
130-139	21	35.0	29	48.3	20	34.5
≥140	19	31.7	15	25.0	8	13.8
Diastolic blood pressure (mmHg)						
<80	12	20.0	14	23.3	12	20.7
80-89	21	35.0	18	30.0	31	53.4
≥90	27	45.0	28	46.7	15	25.9
Diastolic and systolic blood pressure (mmHg) †	N=58	%	N=58	%	N=58	%
Hypertensive	32	55.2	31	53.5	19	32.8
Normotensive	26	44.8	27	46.6	39	67.2

Table 4. Blood pressure categories in women admitted to the maternity ward for hypertension, Rigshospitalet, Denmark, November-December 2019.
† N=58; two participants did not complete all three study measurements and were excluded from the analysis. ‡ Hypertensive: Diastolic ≥90 mmHg or systolic ≥140 mmHg, Normotensive: Diastolic <90 mmHg and systolic <140 mmHg

unacceptable by the International Organization for Standardization (ISO) (10). 36 women had systolic differences and 17 women had diastolic differences exceeding or equal to 5 mmHg when clinical measurements were compared to study measurements.
Three women had systolic differences and seven women had diastolic differences below or equal to -5 mmHg when comparing clinical and study measurements. We observed no distorting trends in the distribution of differences, and there was no correlation between the difference and the mean blood pressure (systolic: R=0.09, diastolic: R=0.17).

DISCUSSION

In this study of 60 women admitted to the maternity ward with suspected or confirmed hypertensive disorders of pregnancy, none of the clinical measurements fulfilled all the recommended guideline steps. When guidelines were followed, systolic blood pressure readings were lower, and the risk of being categorized as hypertensive was decreased. We observed a decrease in blood pressure from the first standardized measurement compared with the mean of the second and third measurements. 22 (38%) women shifted to a 10 mmHg category lower in systolic blood pressure and 15 (26%) in diastolic blood pressure when measurements were performed in adherence to the guidelines.
In non-pregnant adults, two previous studies have made similar observations; Myers et al. found measurements adhering to guidelines to be on average 6 mmHg systolic and 4 mmHg diastolic lower than the clinical measurements. Further analysis showed that clinical measurements had significantly poorer correlation (r=0.34) to awake ambulatory blood pressure (considered the gold standard) compared with measurements following recommended guidelines (r=0.55)(11). Burgees et al. found average differences up to 12 mmHg systolic and 6 mmHg diastolic in a study of 150 participants with chronic hypertension; participants were twice as likely to reach blood pressure target when following recommended measurement technique (12). Our study confirms these disparities in an obstetric population of women with suspected or confirmed hypertensive disorders of pregnancy.

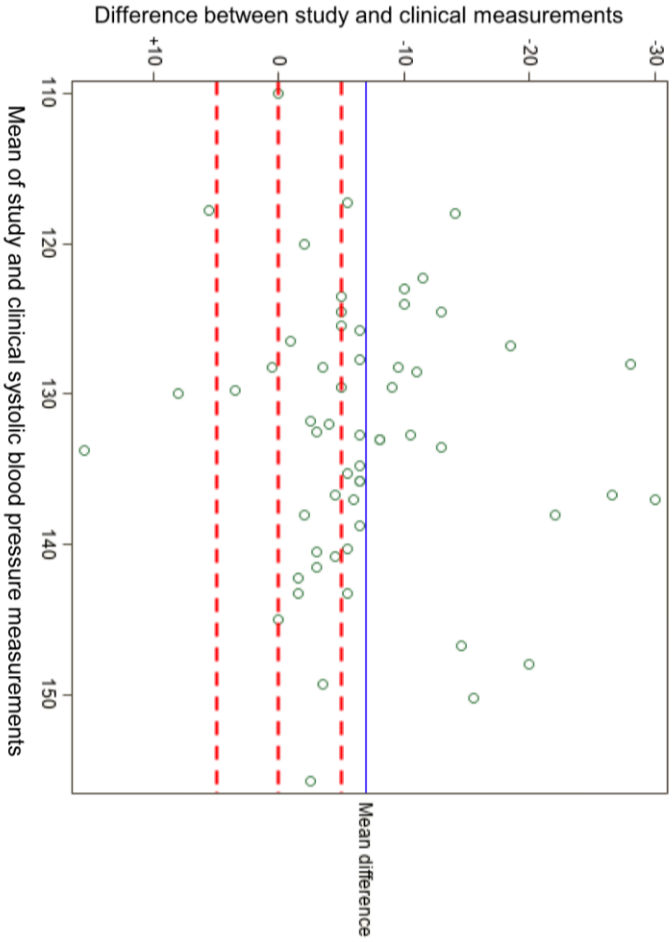

Figure 2a

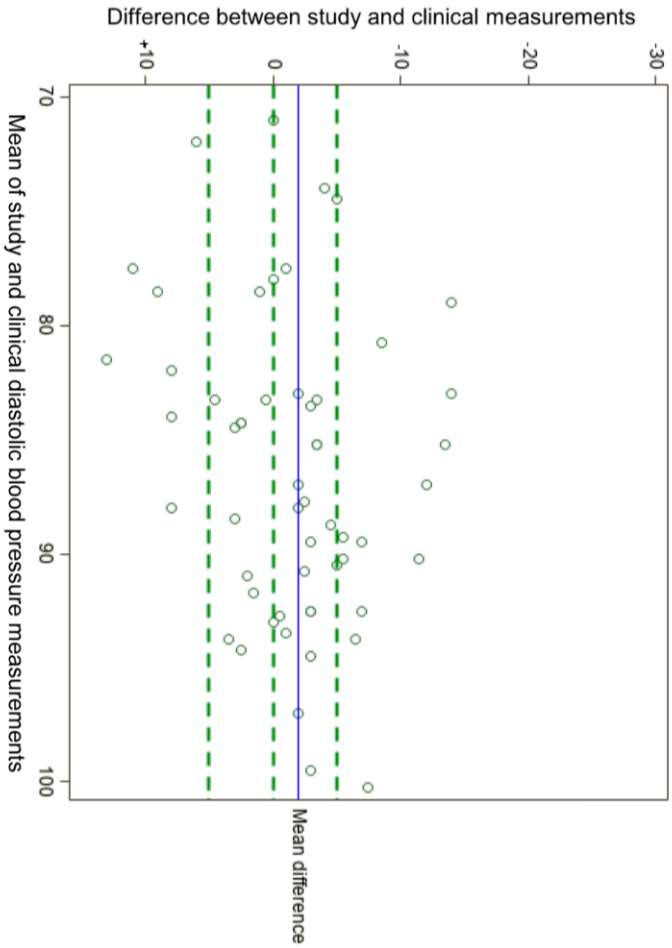

Figure 2b

The larger differences found in systolic pressure than in diastolic pressure between clinical and study measurements might be explained by the fact that changing from supine to sitting position is found to affect systolic pressure more than diastolic pressure (13).

In our study, none of the clinical measurements fulfilled all the recommended guideline steps. The most infrequently followed step was repeating measurements (followed three out of 60 times) which is concerning as we, along with other studies (4), observed significant differences between the first and the mean of the second and third measurement, potentially leading to misdiagnosis. Therefore, non-adherence to this recommendation might explain the differences between the clinical and study measurements found in this study. Another approach to our data could be to use the first or randomize the study measurement used to calculate the differences, however, we judged it out of the scope for this paper as we aimed to compare clinical measurements to a correct assessment, where the mean of second and third measurement is recommended. Only seven out of 60 measurements were performed with the woman sitting in an upright position. Blood pressure has been reported to be higher in supine position (3-10 mmHg systolic and 1-3 mmHg diastolic)(13) and if the arm is resting in the bed it is below the level of the heart, thereby further elevating blood pressure (7–10 mm Hg systolic and 8–11 mm Hg diastolic)(14). Talking during the measurement, which occurred in 53/60 clinical measurements in this study, has been found to increase the mean arterial pressure by 10-15%, especially in patients diagnosed with hypertension (15).

Despite the availability of guidelines, suboptimal blood pressure measurement conditions have been a problem for decades. In a study investigating health care professionals' adherence to recommended guidelines (n=172), none of the participants reported following the American Heart Association's guidelines (7). Since none of the clinical measurements in our study followed guidelines, it is likely that we would make similar findings had we asked health care professionals. Also, as hemodynamics in pregnancy might be different than in the elderly in whom blood pressure monitors are often validated, it is important to use a blood pressure monitor that is validated for use in pregnancy, as we did (16). In this study, the exact same monitor was used for clinical and study measurements, and the type of monitor could therefore not account for the differences. However, using a device with an automatic time interval to standardize the time between measurements may be more accurate.

Efforts to improve adherence to correct measurement techniques are warranted. One solution, which might also decrease the work load of health professionals, is the introduction of self-monitoring which has previously proved feasible and acceptable for pregnant women (17). Future studies could therefore address the element of unattended observations.

Even though we found significant differences between clinical measurements and measurements performed by study personnel, our study did not undergo a power calculation before initiation, and this is a limitation of our study. We were also not able to investigate which aspect of non-adherence to guidelines that caused the difference between clinical and study measurements, and if differences were the same in different BMI and pregnancy status categories because of too few participants in some of the categories. Another limitation of this study is the non-randomization of the order in which the clinical and study measurements were obtained, potentially leading to the participants being more relaxed at the time of the study measurement.

As all women had either suspected or confirmed hypertension, the results of this study are less generalizable to other parts of the obstetric population. However, in this prehypertensive and hypertensive population, even small differences matter. All study measurements were performed by the same researcher (K.H.), thus eliminating interobserver variability. As the median time from the clinical measurements to the study measurements was only nine minutes, it is unlikely that the observed differences were caused by diurnal variation, food or beverage intake, or movement.

Our results suggest that adhering to guidelines when conducting clinical blood pressure measurements may reduce the risk of being incorrectly categorized as hypertensive by 22%. This is important as incorrect categorization may lead to unneces-

sary anxiety in the patient, misdiagnosis of hypertension, which is one of the most common medical pregnancy complications, and the administration of unwarranted medical treatment. Furthermore, as first trimester screening for preeclampsia is becoming increasingly implemented, even small differences in blood pressure may affect the risk algorithm and thereby influence the course of an entire pregnancy regarding comprehensive repeated visits, hospital resources and the woman's experience of having a pregnancy disorder.

CONCLUSION

Adhering to the recommended standardized methods for blood pressure measurement is necessary to ensure the correct diagnosis and monitoring of hypertensive disorders of pregnancy.

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Study concept and design: All authors.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: FL, KH.
Critical revision of the manuscript for important intellectual content: LGP, JAL.
Statistical analysis: FL.
Study supervision: LGP, JAL.

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