Previous studies have associated hypertension with discrepancies between right arm and left arm blood pressure (BP) measurements. The purpose of this study was to determine if there were clinically (defined as ≥10 mm Hg disparity) and statistically significant differences between right arm and left arm BP measurements (systolic, diastolic, or mean) in 34 third-trimester hypertensive gravidas. Thirty-four third-trimester normotensive gravidas were used as controls. No subjects were in active labor.

This study used a cross-sectional, 2-group design with convenience sampling. The protocol for BP measurement followed guidelines of the American Heart Association and the instrument manufacturer.

The results showed a greater range in BP differences between arms for the hypertensive group in the systolic (0.67-26.67 mm Hg) and mean (0-25.67 mm Hg) pressures compared with the normotensive group (systolic, 0-14.33 mm Hg; mean, 0-12 mm Hg). The mean difference in BP between arms was greater for the hypertensive group compared with the normotensive group. Using a 1-tailed t test, the mean difference was statistically significant (P ≤ .05) for the systolic pressure (P = .027) and for the mean pressure (P = .022), but not the diastolic pressure (P = .168). The frequency of clinically significant differences (≥10 mm Hg) was greater for the hypertensive group than for the normotensive group (13 vs 4). These differences in frequencies were not statistically significant with chi-square analysis (systolic, P = .074; diastolic, P = .303; mean, P = .303).

These findings indicated BP discrepancies between arms exist in both normotensive and hypertensive gravidas, with a greater range and frequency of differences in the hypertensive group. This study supports the American Heart Association’s recommendation of bilateral BP assessment.

Key words: Blood pressure, blood pressure discrepancies, blood pressure monitoring, hypertension in pregnancy.
Introduction
Hypertensive disorders are the most common complication of pregnancy and a major factor in maternal death, stillbirths, and neonatal morbidity and mortality throughout the world. Hypertension complicates approximately 10% of all pregnancies, with a higher incidence in women who are nulliparous or carrying multiple fetuses. The hypertensive gravida is predisposed to the development of an array of complications, including abruptio placentae, disseminated intravascular coagulation, cerebral hemorrhage, hepatic failure, and acute renal failure.

Monitoring circulatory responses (through physiological parameters, such as blood pressure [BP]) is routine during the prenatal period to determine the normal progression of the pregnancy. Routine BP assessment can lead to early recognition of hypertension in pregnancy, thus allowing the clinician the opportunity to intervene and affect outcomes positively. The American Heart Association (AHA) recommends that the initial assessment of BP in the hypertensive patient include measurement in both arms. In clinical practice, rarely are bilateral BP measurements performed. More commonly, BP is recorded in the arm that is most accessible or does not have the intravenous line or pulse oximetry probe. In the hypertensive gravida, the practice of not measuring BP initially in both arms could lead to mismanagement resulting in complications for both mother and fetus.

Hypertension has been associated with discrepancies between arms in BP measurement, suggesting that single, unilateral measurements of BP may not be adequate for assessment of the circulatory response. The mechanism for explaining differences in BP between arms is poorly understood. It has been suggested that when a difference occurs between arms in the hypertensive patient, the higher BP be used to guide clinical decisions. This recommendation is made based on the assumption that changes in the arterial vasculature result in a decreased pressure on one side; therefore, the arm with the higher BP more closely represents central aortic pressure. Moll et al. demonstrated angiographic support for innominate or subclavian artery stenosis in 59 (67%) of 88 subjects with suspected vascular occlusive disease with a difference of 10 mm Hg or more in brachial artery pressure between the 2 arms. Yet, 29 (33%) of the 88 subjects with a difference of 10 mm Hg or more had normal intrathoracic vessels, suggesting other explanations for the discrepancies between arms, such as method of measurement, anatomy, or vascular resistance.

Past research studies exploring this phenomenon of BP discrepancies between arms focused on nonpregnant adults. Lacking in the literature were studies focusing on the hypertensive gravida. The purpose of the present study was to determine whether there were clinically (defined as ≥10 mm Hg) and statistically significant differences between right arm and left arm BP measurements (systolic, diastolic, or mean) in third-trimester hypertensive gravidas. Normotensive third-trimester gravidas were used as controls.

The third trimester was important to this study because hypertension associated with preeclampsia does not manifest until after the 20th week of gestation. Blood pressure normally decreases during the first 2 trimesters of pregnancy before returning to “normal” or prepregnancy levels in the third trimester. The normal drop in BP during the first 2 trimesters can mask chronic hypertension, resulting in a failure to identify an elevated BP, leading to a misdiagnosis of normotension.

Two hypotheses were tested. First, the mean difference between right arm and left arm BP measurements in hypertensive gravidas would be greater than the mean difference between right arm and left arm BP measurements in normotensive gravidas for systolic, diastolic, or mean pressures; and second, there would be a greater frequency of clinically significant differences between right arm and left arm BP measurements in hypertensive gravidas than in normotensive gravidas for systolic, diastolic, or mean pressures.

Materials and methods
The study used a cross-sectional, 2-group design. Before initiation of the study, approval was obtained from the institutional review board of University Hospital, Cincinnati, Ohio. All subjects gave written informed consent for participation. The setting included 2 outpatient clinics affiliated with the University Hospital (an urban 707-bed teaching facility): a high-risk perinatal clinic and a routine obstetrical and gynecological clinic.

A nonrandom convenience sample of 68 third-trimester gravidas was obtained from the 2 clinic populations. This sample size was determined from a t test sample size calculation table using a 1-tailed alpha of .05, a moderate effect size
of 0.60, and a power of 0.80. The subjects were equally divided into 2 groups (34 hypertensive and 34 normotensive). Inclusion criteria were pregnant women of 26 weeks’ gestation or more and age 18 years or older. Hypertensive subjects had a documented medical diagnosis of hypertension. The hypertensive group consisted of chronic hypertension (n = 18), transient hypertension (n = 2), or pregnancy-induced hypertension (n = 14). Normotensive subjects had no history of hypertension. No subjects were in active labor. Excluded from the study were subjects with perinatal emergencies, an irregular heart rate with a beat-to-beat variation of greater than 15%, and/or injury to either arm that would have eliminated bilateral BP measurement.

Using the oscillometric technique, the Dinamap XL, Model 9300 (Johnson & Johnson Medical, Inc, Tampa, Fla) was the instrument used for measurement of all BPs. The same instrument was used for all measurements. The accuracy of the instrument has been reported as meeting the Association for Advancement of Medical Instruments (1987) standards of ± 5 mm Hg mean difference and an SD of 8 mm Hg, when comparing brachial artery BP measurements taken with the Dinamap XL, Model 9300 and the intra-arterial BP method. Milsom et al reported a close correlation between systolic and diastolic BP determined intra-arterially and with the Dinamap (r = 0.92, r = 0.90, respectively) in a study of 10 third-trimester healthy gravidas. They also reported no significant difference (P > .05) in the reproducibility of individual BP values determined intra-arterially or with the Dinamap. Their conclusion was that the Dinamap was a reliable instrument for the measurement of changes in BP in late pregnancy. To strengthen accuracy of the measurements before each data collection, a calibration check of the Dinamap was performed against a mercury sphygmomanometer.

Subjects were asked to refrain from eating, drinking, or smoking for at least 30 minutes and to sit and rest quietly in the observation room with an empty bladder 5 minutes before data collection. The radial pulse was monitored for 1 minute to establish the presence of a regular heart rate. Subjects were seated at a table with their arms supported at heart level and with palm surface up.

Nonsimultaneous BP measurements were obtained. Selection of the arm to measure the first BP was randomized using a table of random numbers. Random selection of arms was designed to decrease reported bias of which arm had the highest BP. The subject’s upper arm circumference was measured to meet AHA’s guidelines for proper cuff size: a bladder width that is 40% of the circumference of the upper arm at the midpoint and a bladder length that is 80% of the arm circumference. Three BP measurements were taken consecutively in the first arm with a 30-second delay between measurements. Without changing the subject’s position, the same cuff was reapplied to the other arm with 3 consecutive measurements recorded. The 3 measurements were averaged into a single systolic, diastolic, and mean pressure for each arm. The difference between arms was then determined.

Demographic data recorded for each subject included age, weight, height, arm circumference, duration of gestation, gravidity, parity, and ethnicity (Table 1). Subjects were paid $10 for their participation in the study. All data were collected by the author.

### Results

Statistical significance for all analyses was established a priori at P ≤ .05. Analysis of variance (ANOVA) of the demographic data showed a statistically significant difference between the 2 groups in age, arm circumference, and weight. A further statistical analysis of the demographic data using

<table>
<thead>
<tr>
<th>Table 1. Comparison of means of demographic characteristics*</th>
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</thead>
<tbody>
<tr>
<td>Characteristic</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Age (y)†</td>
</tr>
<tr>
<td>Gravidity</td>
</tr>
<tr>
<td>Parity</td>
</tr>
<tr>
<td>Gestational age (mo)</td>
</tr>
<tr>
<td>Height (in)</td>
</tr>
<tr>
<td>Weight (lb)†</td>
</tr>
<tr>
<td>Arm circumference (cm)†</td>
</tr>
<tr>
<td>Black</td>
</tr>
<tr>
<td>White</td>
</tr>
</tbody>
</table>

* Data are given as mean (SD) except for race, which is the number of subjects.
† Statistically significant difference (P ≤ .05) by analysis of variance
ANOVA showed no statistically significant relationship between right arm and left arm BP differences and any of the demographic characteristics.

To test the first hypothesis, t tests were used to compare the absolute mean difference between the right arm and left arm systolic, diastolic, and mean BP of the 2 groups. The results demonstrated the hypertensive group, compared with the normotensive group, had a greater absolute mean difference in the systolic and mean BP between arms that was statistically significant (Tables 2 and 3). No statistically significant differences were found between the 2 groups in the absolute mean difference between arms in the diastolic pressure (Table 4). Also note in Tables 2 and 3, the hypertensive group compared with the normotensive group had a substantially greater range of BP differences between arms in the systolic and mean pressures.

Frequencies of clinically significant differences (≥10 mm Hg) occurring in the systolic, diastolic, and mean BPs were determined to test the second hypothesis. A total of 17 clinically significant differences were measured. Chi-square analysis showed no statistically significant differences between the 2 groups and frequencies for the systolic, diastolic, or mean (Table 5). Although not statistically significant, the hypertensive group had a greater frequency of clinically significant differences measured between arms across all 3 pressures. Of the 17 clinically significant differences measured, 6 were assessed in the right arm, and 11 were assessed in the left.

Clinically significant differences were measured in 11 subjects: 8 (24%) of 34 hypertensive subjects and 3 (9%) of 34 normotensive subjects. When clinically significant differences were measured in the systolic, diastolic, or mean pressures, the first arm used for BP recording had the higher pressure in 5 (45%) of 11 subjects.

**Discussion**

These results demonstrate that BP discrepancies exist in hypertensive and normotensive third-

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**Table 2. Comparison of right arm and left arm mean differences and range of differences in the systolic pressure between groups**

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean difference†</th>
<th>Range</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normotensive</td>
<td>4.4</td>
<td>0-14.3</td>
<td>3.4</td>
</tr>
<tr>
<td>(n = 34)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertensive</td>
<td>6.9</td>
<td>0.7-26.7</td>
<td>6.4</td>
</tr>
<tr>
<td>(n = 34)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Values are reported in mm Hg.
† Statistically significant (P ≤ .05 by 1-tailed t test)

**Table 4. Comparison of right arm and left arm mean differences and range of differences in the diastolic pressure between groups**

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean difference†</th>
<th>Range</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normotensive</td>
<td>2.9</td>
<td>0-12.3</td>
<td>2.6</td>
</tr>
<tr>
<td>(n = 34)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertensive</td>
<td>3.5</td>
<td>0.3-12.3</td>
<td>3.1</td>
</tr>
<tr>
<td>(n = 34)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Values are reported in mm Hg.
† No statistically significant differences (P ≤ .05 by 1-tailed t test)

**Table 5. Frequencies of clinically significant differences measured between arms in each group**

<table>
<thead>
<tr>
<th>Group</th>
<th>Normotensive (n = 34)</th>
<th>Hypertensive (n = 34)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Diastolic</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Mean</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>13</td>
</tr>
</tbody>
</table>

* No statistically significant differences were found (P > .05) by chi-square analysis.
trimester gravidas, with a greater frequency and range in hypertensive gravidas. In clinical practice, ignoring a discrepancy between right and left arm BPs may lead to inappropriate clinical decisions. If BP is monitored only in 1 arm, the gravida may be assessed improperly as normotensive, while BP in the other arm may reveal the true hypertensive state. According to AHA’s guidelines for hypertensive patients, the arm with the higher pressure should be used to guide clinical decisions.6

One such incident occurred in the present study. Subject 1 in the hypertensive group had a diagnosis of pregnancy-induced hypertension, and conservative treatment of bedrest and an oral antihypertensive medication (methyldopa [Aldomet]) were prescribed. Measurement of bilateral BPs revealed a right arm BP of 150/80 mm Hg (mean, 105 mm Hg) compared with a left arm BP of 175/92 mm Hg (mean, 131 mm Hg). Basing clinical decisions on the right arm would have resulted in no change in clinical treatment since this BP was in her normal range. Yet the left arm BP was clearly elevated, indicating that current therapy was inadequate, and a change in therapy was needed.

Based on previous reports in the literature,7,10,18 clinically significant differences were defined in the present study as 10 mm Hg or more. In the clinical setting, the degree of difference between arms that is clinically significant is subjective. A clinically significant difference in BP between arms depends on the patient’s BP and the overall clinical picture. The maximum difference measured between arms in the systolic pressure of 26.67 mm Hg in the present study most likely would be considered clinically significant.

In both groups more clinically significant differences were measured between arms in the systolic pressure compared with the diastolic or mean pressure. This finding is similar to those reported for previous studies.19 These studies also suggested that as BP increases (as with hypertension), the incidence of BP differences between arms also increases. Data from the present study supported this finding; that is, in the hypertensive group, a greater frequency and range of differences were measured, suggesting that as BP increases differences in BP between arms also increases. These results would suggest an increased variability in the BP in the hypertensive gravida and, in particular, an increased variability in the systolic pressure. This was confirmed by the SDs reported in Tables 2, 3, and 4. These SDs showed not only an increased variability in the mean differences between arms in hypertensive gravidas compared with normotensive gravidas, but also that the greatest variability was in the systolic and the least in the diastolic pressures for both groups.

Swallow19 reported the arm monitored first tended to have the higher pressure when BP differences existed. In the present study, after randomizing the arm to be monitored first, only 45% of the first arms monitored had the higher pressure. However, the left arm predominated as the arm with the higher pressure when a clinically significant difference was measured. The clinician should not assume left-arm dominance in third-trimester gravidas; other studies have reported conflicting results in subjects with BP discrepancies between arms, including dominance in the right arm7 and in neither arm,10,20

Previous studies8,10 have reported approximately 5% of the normotensive subjects and 15% of the hypertensive subjects had differences in BP between arms of 10 mm Hg or more. Findings of the present study indicated higher percentages of BP differences in both groups, but this may have been due to the small sample.

Subjects in the present study, because of convenience sampling and the use of 1 institution for data collection, may not be representative of normotensive and hypertensive third-trimester gravidas, thus affecting the generalizability of the results. Furthermore, certain variables, such as medication and coexisting diseases that may have affected BP, were not controlled for.

Internal validity determines the extent to which the differences in BP measurements between the right arm and left arm in the 2 groups reflected the true relationship of these variables. The single largest threat to the study’s internal validity was with instrumentation, that is, the difference between the actual BP and the measured BP. Nonsimultaneous measurement of the BP could have led to errors in precision. This nonsimultaneous measurement may have introduced random error due to moment-to-moment variation of the BP. To limit this error, 3 BPs were measured in one arm 30 seconds apart and then repeated in the other arm. These 3 BPs were then averaged into a single BP for each arm.

Recommendations for further study include a replication of this study with a larger sample to compare results. Changes in design, such as use of simultaneous BP measurements and subject follow-up to assess whether BP discrepancies continued over time, would strengthen the study. Prospective arteriography studies of subjects with discrepancies in BP between arms are needed to explore the mechanism of these differences.
Conclusion

In clinical practice, rarely is BP measured in both arms as part of the initial assessment of hypertensive patients. This is in conflict with recommendations by the AHA and the findings of previous research studies.\(^7\)\(^\text{12}\) If BP is not assessed in both arms, the healthcare provider may be basing clinical decisions on an incorrect physiological parameter. The results of the present study support the use of bilateral BP assessment in hypertensive and normotensive third-trimester gravidas to determine whether discrepancies exist. Following AHA’s recommendations, the arm with the higher pressure should be used to guide clinical decisions.

REFERENCES


AUTHOR

W. Terry Ray, CRNA, PhD, is an independent anesthesia contractor in Little Rock, Ark. He was affiliated with the University of Cincinnati College of Nursing, Cincinnati, Ohio, during this research project.

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