Consistency of Blood Pressure Differences Between the Left and Right Arms

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Background: It is unclear to what extent interarm blood pressure (BP) differences are reproducible vs the result of random error. The present study was designed to resolve this issue.

Methods: We enrolled 147 consecutive patients from a hypertension clinic. Three sets of 3 BP readings were recorded, first using 2 oscillometric devices simultaneously in the 2 arms (set 1); next, 3 readings were taken sequentially for each arm using a standard mercury sphygmomanometer (set 2); finally, the readings as performed for set 1 were repeated (set 3). The protocol was repeated at a second visit for 91 patients.

Results: Large interarm systolic BP differences were consistently seen in 2 patients with obstructive arterial disease. In the remaining patients, the systolic BP and the diastolic BP, respectively, were slightly higher in the right arm than in the left arm by 2 to 3 mm Hg and by 1 mm Hg for all 3 sets (P<.01 for all). For the systolic BP and the diastolic BP, respectively, the numbers of patients who had a mean interarm difference of more than 5 mm Hg were 11 (7.5%) and 4 (2.7%) across all 3 sets of readings. Among patients who repeated the test, none had a consistent interarm BP difference of more than 5 mm Hg across the 2 visits.

Conclusions: The interarm BP difference was consistent only when obstructive arterial disease was present. Although BP in the right arm tended to be higher than in the left arm, clinically meaningful interarm differences were not reproducible in the absence of obstructive arterial disease and are attributable to random variation.

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The accurate assessment of blood pressure (BP) is vital for the correct diagnosis and treatment of hypertension. Blood pressure measurement guidelines of the American Heart Association,1 World Health Organization–International Society of Hypertension Guidelines,2 European Society of Hypertension–European Society of Cardiology,3 and British Hypertension Society4 recommend that BP should be measured in both arms at the initial patient assessment and that, in the event a difference is observed, the arm with the higher pressure should be used for all future measurements. A disparity in BP between the 2 arms is well recognized as a consequence of anatomical abnormalities such as subclavian artery stenosis,5 but significant interarm BP differences have also been reported in patients without apparent arterial disease. One study6 performed among older patients reported a mean interarm difference of 4.2 vs 3.6 mm Hg, with 10% of patients showing a systolic BP (SBP) difference of more than 10 mm Hg. A second study7 reported corresponding figures of 6.3 vs 5.1 mm Hg, with 20% of the patients showing an SBP difference of more than 10 mm Hg. A third study8 of younger patients with hypertension found a mean interarm difference of 5.4 vs 3.1 mm Hg, with 14.2% of patients showing an SBP difference of more than 10 mm Hg. A fourth study,9 conducted in an emergency department setting, showed a mean interarm difference of 10.5 vs 7.6 mm Hg, with the difference exceeding 10 mm Hg in 38.7% of patients. In contrast, a fifth study10 did not observe such differences.

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Most of these cited studies used only a few readings to assess the interarm difference on a single occasion, and the methods used to assess the interarm BP differences varied, including mercury sphygmomanometers10 and oscillometric devices.6-9 Some researchers used sequential readings,8-10 while other investigators believed that readings taken simultaneously in the 2 arms would be more accurate.5,7,9 A major problem inherent in all of these studies is the spontaneous variability of BP, which can produce spurious differences between the 2 arms if only a few readings are used. We conducted the present study to determine how frequently a reproducible difference
exists between BP in the 2 arms and whether the methods used to detect it affect the results.

METHODS

STUDY COHORT

This was a prospective observational study. One hundred forty-seven consecutive subjects were recruited from the hypertension clinic at Columbia University New York Presbyterian Hospital, New York City. None of the subjects had arrhythmia or chronic renal disease (serum creatinine level, >2.2 mg/dL [>194 µmol/L]) at examination. The following demographic variables were assessed at the initial visit: age, sex, handedness, race/ethnicity, body mass index, and history of cardiovascular disease. Arm circumference was measured, and the appropriate cuff size was selected. The patients sat quietly with their backs supported without crossing their legs and with both arms supported at heart level for 5 minutes. Three sets of 3 BP readings were recorded, first using 2 identical oscillometric devices (model UA767-PC; A & D Co, Ltd, Tokyo, Japan) simultaneously in the 2 arms (set 1); next, 3 readings were taken sequentially for each arm using a standard mercury sphygmomanometer (set 2); finally, the oscillometric readings were repeated as performed for set 1 (set 3). The oscillometric devices in each arm were not linked, and these devices did not measure BP exactly simultaneously. These devices were checked regularly for accuracy at intervals during the study. At the beginning of the visit, a coin was flipped to determine which of the 2 oscillometric devices (A or B) would be assigned to which arm for set 1. For set 3, the assignment was reversed. The coin was flipped a second time to determine which arm would be used first for the sequential mercury readings (set 2). Data from 2 patients who had known obstructive arterial disease were analyzed separately from those of the remaining 145 patients. Ninety-one of 145 patients had these measurements repeated at a second clinic visit. When 1 reading for any set of 3 consecutive measurements on the same arm differed from the other 2 readings by more than 25 mm Hg SBP or more than 20 mm Hg diastolic BP (DBP), the reading was excluded from the analyses. Consequently, 21 readings (10 SBP and 11 DBP readings) that were considered measurement errors were excluded from the analysis.

This study was approved by the Institutional Review Board of Columbia University. Written informed consent was obtained from all patients.

STATISTICAL ANALYSIS

For each set of BP readings, those for each arm were averaged separately, and the interarm difference was defined as the difference in BP between the right arm and the left arm for SBP and DBP. The interarm BP mean absolute differences between the 2 arms were compared using paired t tests. The associations between BP differences obtained for the between-set and between-visit comparisons were evaluated using the intraclass correlation coefficient. For all analyses, a significance level of P < .05 (2-tailed) was used. All statistical analyses were performed using commercially available software (SPSS version 13.0; SPSS Inc, Chicago, Ill).

RESULTS

Initially, 150 consecutive patients seen in the hypertension clinic were enrolled for the study. Among them, 2 patients who had obstructive arterial disease had large mean interarm SBP differences (76 and 42 mm Hg), and their data are given in Table 1. The large interarm BP differences in these patients were reproducible not only between the sets but also between the 2 visits. Three patients with high proportions of inaccurate BP readings were excluded because of measurement errors or because more than 1 reading for any set of 3 consecutive measurements differed from the other 2 by more than 25 mm Hg SBP or more than 20 mm Hg DBP in each arm. Therefore, data from 145 patients were used in the following analyses. As summarized in Table 2, 130 (89.7%) had a diagnosis of hypertension, 18 (12.4%) had a diagnosis of type 2 diabetes mellitus, 6 (4.1%) had experienced claudication, and 19 (13.1%) had a history of cardiovascular disease (stroke, heart attack, angina, angioplasty, or coronary bypass surgery). One hundred thirty-three patients (91.7%) were right-handed, but the mean arm circumferences were similar between the 2 arms.

The mean BP values for each of the 3 sets of readings for the right and left arms among the 145 patients are given in Table 1. The large interarm BP differences in these patients were reproducible not only between the sets but also between the 2 visits. Three patients with high proportions of inaccurate BP readings were excluded because of measurement errors or because more than 1 reading for any set of 3 consecutive measurements differed from the other 2 by more than 25 mm Hg SBP or more than 20 mm Hg DBP in each arm. Therefore, data from 145 patients were used in the following analyses. As summarized in Table 2, 130 (89.7%) had a diagnosis of hypertension, 18 (12.4%) had a diagnosis of type 2 diabetes mellitus, 6 (4.1%) had experienced claudication, and 19 (13.1%) had a history of cardiovascular disease (stroke, heart attack, angina, angioplasty, or coronary bypass surgery). One hundred thirty-three patients (91.7%) were right-handed, but the mean arm circumferences were similar between the 2 arms.

The mean BP values for each of the 3 sets of readings for the right and left arms among the 145 patients are given in Table 3. The mean SBP in the right arm was consistently higher than that in the left arm for all 3 sets of BP measurements taken at visit 1 except for a marginal difference for set 3. The mean SBP in the right arm for each set of readings was also significantly higher than in the left arm at visit 2. In addition, a slightly higher mean DBP in the right arm was observed for set 1 and for set 2 at visit 1 and for set 2 at visit 2. This trend was observed to some extent in left-handed and right-handed patients, but the difference was not statistically significant (data not shown).

Figure 1 shows scatterplots of the interarm SBP differences between set 1 and set 2. As shown, the interarm SBP differences between set 1 and set 2 were weakly although significantly correlated (n = 145, r = 0.21, P = .01).
even after excluding the 2 patients with obstructive arterial disease. Between-set and between-visit correlation coefficients of interarm differences are given in Table 4. A significant correlation was seen between set 1 and set 2 at visit 2 (n=91, \( r=0.38, P<.001 \)) in addition to that at visit 1, but none of the other between-set correlations were significant. For DBP, there was no clear pattern for the correlations across sets and visits, although there were 2 significant but negative correlations.

To evaluate the effect of measurement technique on the interarm BP difference, the mean interarm BP differences assessed using simultaneous measurements (oscillometric for set 1 and set 3) vs sequential measurements (auscultatory for set 2) were compared (Table 5).
The interarm BP difference using the sequential method was significantly larger than that using the simultaneous method for SBP at visit 1 (\(P = .008\)) and for DBP at visit 2 (\(P = .03\)).

At visit 1, only 2 of 145 subjects exhibited interarm SBP differences of more than 5 mm Hg that were consistent from the first to the eighth readings of 9 readings taken (including sets 1 through 3). One subject had a history of claudication, but the other patient was free from known cardiovascular disease. The number of patients who showed more than a 5–mm Hg interarm difference decreased progressively as the number of readings increased (Figure 2).

Bland-Altman plots did not show any tendencies for the interarm BP differences to vary as a function of the mean SBPs (Figure 3).

As already noted, 91 patients agreed to repeat the test at a second clinic visit. The number of patients with absolute interarm BP differences of more than 5 mm Hg decreased as the number of readings increased, as observed at visit 1 (Figure 2B). For SBP and DBP among the 91 patients, 21 (23.1%) and 4 (4.4%), respectively, had a mean difference of more than 5 mm Hg at the first pair of all 9 readings on both days. However, none of the patients (except for the 2 patients with previously diagnosed obstructive arterial disease) had consistent interarm BP difference of more than 5 mm Hg for all 18 readings at both visits. The intraclass correlation for all 18 readings at visit 1 and visit 2 was essentially zero (\(r = 0.00, P = .93\)). The between-visit SBP correlation was significant only for set 1 (\(r = 0.43, P < .001\)); neither set 2 nor set 3 showed any significant correlation between the 2 visits (Table 4).

**Table 5. Interarm Blood Pressure (BP) Differences Using the Simultaneous vs Sequential Method**

<table>
<thead>
<tr>
<th>BP Difference, mm Hg</th>
<th>Simultaneous Method (Set 1 and Set 3)</th>
<th>Sequential Method (Set 2)</th>
<th>(P) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic</td>
<td>1.5 ± 3.3</td>
<td>3.1 ± 6.4</td>
<td>.008</td>
</tr>
<tr>
<td>Diastolic</td>
<td>0.9 ± 2.5</td>
<td>1.4 ± 3.8</td>
<td>.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>2.4 ± 5.4</td>
<td>2.5 ± 6.6</td>
<td>.86</td>
</tr>
<tr>
<td>Diastolic</td>
<td>0.1 ± 2.5</td>
<td>1.3 ± 5.1</td>
<td>.03</td>
</tr>
</tbody>
</table>

*Data are given as mean±SD.

**Figure 2.** Numbers of patients with more than a 5–mm Hg interarm blood pressure (BP) difference over time at visit 1 (A) and at visit 2 (B). For the systolic BP and the diastolic BP, respectively, the numbers of patients who had a mean interarm difference of more than 5 mm Hg were 11 (7.5%) and 4 (2.7%) across all 3 sets of readings. The x-axis indicates the cumulative number of systolic BP readings used to determine the interarm difference; y-axis, the number of patients who consistently had more than a 5–mm Hg interarm difference.

**Figure 3.** Bland-Altman plots of systolic blood pressure (BP) for the 3 sets of measurements taken at visit 1. The x-axis indicates the mean of 3 systolic BP readings; y-axis, the interarm BP differences for each set.

**COMMENT**

In the present study, we found that there is a small but persistent interarm BP difference among patients attending a hypertension clinic who did not have clinically significant obstructive arterial disease. Blood pressure in the right arm was consistently higher than that in the left arm regardless of the handedness, and the difference was still observed at visit 2. We also found that, in the absence of known obstructive arterial disease, apparently large interarm differences (>10 mm Hg) were not consistent over time and were dependent on the number of readings used to define them, leading us to conclude that routinely taking measurements on a second arm does not improve the accuracy of the measurement in persons without significant obstructive arterial disease. On the other hand,
marked and persistent interarm BP disparity should prompt an investigation for occlusive arterial disease.

**REPRODUCIBILITY**

In this study, the percentage of patients with an interarm SBP difference of more than 10 mm Hg was 14.5% after the first set of readings. This number was similar to that (14.2%) in the study by Arnett et al,6 although other studies6,7,10-11 have shown values varying from 1.4% to 39%. Most of the previous studies measured BP only a few times to define the interarm differences, with measurements performed once,12 twice,7 3 times,13 4 times,13 or not described.3,14 One study10 measured the interarm difference using 12 readings and found that the interarm BP difference was small (0.9 vs 0.7 mm Hg for SBP vs DBP). However, the study excluded 2 subjects who had interarm SBP differences of more than 20 mm Hg. In contrast to these earlier studies, the interarm BP difference in our study was inconsistent for all but 2 patients when BP was measured multiple times. The interarm BP differences within the same individual were inconsistent from one set of readings to the next. However, Table 4 summarizes that for SBP there was a significant correlation between the interarm differences measured for set 1 across the 2 visits but not for set 2 and set 3. Therefore, the interarm difference is partially reproducible only within the first 3 readings, suggesting that it might be a temporal phenomenon. This finding is of potential importance because it may explain why studies that used small numbers of readings to define interarm differences obtained positive results.

**INTERARM BP DIFFERENCES**

In the present study, BP in the right arm was significantly higher than in the left arm at visit 1 and at visit 2, although the placement of the 2 oscillometric devices for set 1 and set 3 and the arm selected for the first of the sequential readings for set 2 were randomized. This is consistent with most previous studies6,7,10-11,13,15-17 but not all of them.11,14 The fact that we found the same difference at visit 1 and at visit 2 suggests that this difference, while small, is consistent. Although 133 (91.7%) of the subjects were right-handed, the arm circumference was not different between the 2 arms. Regardless of the handiness, slight differences of anatomical structures and hemodynamic profiles might have also affected the result15 because BP in the right arm also tended to be higher in 15 left-handed subjects. These speculations notwithstanding, further research is required to adequately explain the reasons for the interarm BP difference.7 Fortunately, although the difference was statistically significant, we believe that the small magnitude of interarm BP difference can be ignored clinically. None of the major guidelines on BP measurement have described this difference.1,4

**SEQUENTIAL VS SIMULTANEOUS METHODS**

Some previous studies8,10,12 used sequential rather than simultaneous readings. One study9 evaluated the interarm BP difference using the sequential method for the first 300 subjects and simultaneously for the next 310 subjects in a hospital emergency department setting and found that the simultaneous method tended to demonstrate a smaller interarm BP difference than the sequential measurements, as would be expected. However, the number of readings was not specified. We included both methods in this study and confirm that BP in the right arm was higher than that in the left arm for the simultaneous oscillometric (set 1 and set 3) and sequential mercury (set 2) readings. The interarm SBP difference was slightly but significantly higher when readings were performed by a sequential method using a mercury sphygmomanometer than by the simultaneous method using 2 oscillometric devices, probably because of Traube-Hering-Mayer waves, respiratory effects, or the larger time difference in the sequential method. In the present study, strictly simultaneous measurements could not be performed because the 2 oscillometric devices were not actually joined to each other.18 Even when simultaneous measurements were used, large interarm differences were observed in previous studies.6,7

**BETWEEN-VISIT DIFFERENCE**

To our knowledge, no previous study evaluated the between-visit reproducibility of interarm BP differences. In the present study, the interarm BP difference was examined at a second clinic visit to assess this and showed conclusively that, except for the 2 patients with obstructive arterial disease, the interarm BP difference was not reproducible using the mean values for each of the 3 sets or for all of the 18 readings. The between-visit interarm SBP differences correlated significantly only for set 1; there were no correlations for set 2 or set 3 (Table 4). Between-visit BP variations are known to be large,19 and 6 or more visits may be needed to reduce the between-visit BP variation.20 The results in the present study indicate that the apparent interarm BP difference in most patients with hypertension was simply the result of random variation.

**CONCLUSIONS**

These data suggest that there is a small but consistent BP difference between the 2 arms, being slightly higher on the right, but that larger differences in the range of 5 to 10 mm Hg are almost always due to random variation. There is a small population of patients with obstructive arterial disease who have large interarm differences (eg, ≥40 mm Hg) that are persistent across successive measurements taken on the same day and across measurements taken on different days. The traditional recommendation to perform a few measurements in both arms and to subsequently use the arm with the higher readings, even if there is no evidence of arterial disease, is not supported by our results (and is probably rarely followed in practice). However, it is of great importance to identify the few patients who have large differences. While we support the recommendation to check BP in both arms at the first visit, our data suggest that apparent differences of as much as 10 mm Hg can be safely ignored. The issue of the higher BP in the right...
arm is more problematic: the difference is too small to be detected on routine checking, and we cannot say whether the right arm or the left arm pressure correlates more closely with risk. However, the findings provide support for using sequential measurements from the same arm rather than simultaneous measurements from the 2 arms for validating monitors.

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