Accuracy of Auscultatory Blood Pressure Measurements in Hypertensive and Obese Subjects

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SUMMARY In 59 treated or untreated hypertensive subjects and 52 obese subjects (normotensive or hypertensive), intraarterial blood pressure (BP) was compared to simultaneous auscultatory measurements. In the hypertensive group, arm circumference was less than 35 cm compared to over 35 cm in the obese subjects. The occluding cuffs were 12 x 35 cm and 15 x 43 cm respectively. Mean difference between auscultatory and intraarterial systolic BP (SBP) was among the hypertensive -8.8 mm Hg (SD 10.0 mm Hg, range +13/-28) and among the obese -3.1 mm Hg (SD 13.8 mm Hg, range +19/-49). Mean difference auscultatory-intraarterial diastolic BP (DBP) Phase V was among the hypertensive patients +10.8 mm Hg (SD 12.5 mm Hg, range +29/-8), and among the obese +5.5 mm Hg (SD 7.3 mm Hg, range +20/-10). Thus, a 15 x 43 cm cuff used in obese subjects with an arm circumference exceeding 35 cm gave quite as reliable measurements as a 12 x 35 cm cuff used in hypertensive subjects with "normal" dimension of the upper arm (<35 cm). It is emphasized that there is a wide scatter in the interindividual differences, and it is argued that a comparison between auscultatory and intraarterial BP should be performed in patients with poorly controlled hypertension.

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KEY WORDS • blood pressure • measurement of blood pressure • hypertension • obesity

SEVERAL studies have been published concerning the difference between direct (intraarterial) and indirect (auscultatory) measurement of brachial artery blood pressure (BP).1,13 In these studies nearly all the subjects have been normotensive controls, and only a few have been treated or untreated hypertensives. In both obese and nonobese hypertensive subjects, we have compared the auscultatory measurements with simultaneous short-lasting intraarterial values in order to evaluate whether there is an artifact using the conventional cuff technique. The aims of the present study were to compare auscultatory and intraarterial readings in a group of consecutively referred hypertensive subjects, and to evaluate similar comparisons performed among obese subjects (hypertensive and normotensive).

Material and Methods

A total of 59 treated or untreated hypertensive patients were investigated (table 1). Before treatment, they had auscultatory diastolic BP (DBP) Phase V greater than 105 mm Hg, in repeated ambulatory measurements. The patients were consecutively referred from outpatient clinics and medical wards. All in the hypertensive group had an upper arm circumference less than 35 cm on the day of direct and indirect BP measurements. With these patients, a 12 x 35 cm arm cuff was used.14 If their upper arm circumference was greater than 35 cm, they were referred to the obese group, where a bigger cuff was used.15

There were 52 obese patients, on whom a cuff 15 x 43 cm was used.14 13 They were sent to us either because of hypertension or because they were awaiting an intestinal bypass shunt operation for morbid obesity and were to be followed for changes in arm BP before and after the weight loss.
Comparison Between Auscultatory and Intraarterial Blood Pressure

The patients were placed in the supine position for about 15 minutes. Prior to the intraarterial measurements, auscultatory BP was measured twice on both arms. In none of the patients did the blood pressure in the two arms differ more than ± 10 mm Hg for both systolic BP (SBP) and DBP (Phase V). Seven patients (three hypertensive and four obese subjects) were excluded from the study due to a difference of more than 10 mm Hg between auscultatory BP in the two arms (SBP = 15, 15, 18, and 29 mm Hg; DBP = 11, 11, and 13 mm Hg). In seven patients (one hypertensive and six obese subjects), the intraarterial measurements could not be performed due to difficulties in cannulation of the deep-lying and/or very thin arteries.

Intraarterial Measurements

Intraarterial measurements in the right arm were performed after local anesthesia with a sharp needle 4-cm long (gauge 21, outer diameter 1.0 mm, inner diameter 0.7 mm) connected to an Elema-Schonander capacitance transducer (Postack, Solna, Sweden) through a rigid polyethylene tube 20-cm long. The needle was inserted in the right brachial artery. In all intraarterial tracings, the dicrotic notch was clearly established before the comparison was performed.

Auscultatory Measurements

Triplicate auscultatory measurements with an ordinary mercury manometer on the left arm were used for comparison with intraarterial measurements. The cuff was initially inflated to about 40–50 mm Hg above the expected SBP. After waiting a few seconds, deflation began at a rate of about 5 mm per pulse beat. In the area around SBP, the deflation rate was + 15 to − 5 mm Hg; the deflation rate changed to about 2 mm Hg per pulse beat, which made possible readings with an approximation of 2 mm Hg. Between the SBP and expected DBP, the deflation rate was about 5 mm Hg per pulse beat, but in the area around DBP Phase V (cessation of Korotkoff sounds), the deflation rate was again 2 mm Hg per pulse beat, thus permitting a reading of DBP with an approximation of 2 mm Hg. The DBP Phase IV (muffling of the Korotkoff sounds) was not recorded in the study.

We have used this auscultatory measurement technique for years and have found it applicable to all readings of auscultatory BP, particularly where measurement accuracy is important, such as in clinical trials. Before the study, the authors had tested auscultatory BP measurements and interobserver variation of BP readings in a few patients although no systematic technique for comparison was used by all authors.

In this study when auscultatory SBP and DBP Phase V were read, the intraarterial tracings were marked by a technician so that the exact intraarterial value could be calculated after the comparison. Following the measurements, the linearity of the transducer-manometer system was clarified using increasing fixed pressures (ie., 0, 50, 100, 150, 200, 250 mm Hg and then back to 0, the "staircase-test"). The degree of damping calculated using the square-wave test was about 0.3–0.4, i.e., a slightly underdamped system. The natural frequency of the system calculated from the square-wave test was about 15 to 20 Hz.

Results

The overall results are given in table 2 and figure 1. In both the hypertensive group and the obese group, auscultatory SBP was on the average a few mm Hg below that of intraarterial SBP, the mean difference being − 8.8 mm Hg and − 3.1 mm Hg respectively. The individual differences varied considerably, as expressed in both SDDIFF and range (table 2). Among the hypertensive subjects, auscultatory DBP Phase V was on the average + 10.8 mm Hg above the intraarterial DBP, and among the obese subjects, + 5.5 mm Hg above intraarterial DBP. In both groups the interindividual differences varied considerably, as expressed by SDDIFF and range (table 2 and fig. 1).

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Auscultatory BP (mm Hg)</th>
<th>Intraarterial BP (mm Hg)</th>
<th>Auscultatory arterial BP (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertensive (n = 59)</td>
<td>174.0/108.4</td>
<td>182.8/97.6</td>
<td>− 8.8/ + 10.8</td>
</tr>
<tr>
<td>Mean</td>
<td>154.9/92.3</td>
<td>158.0/86.8</td>
<td>− 3.1/ + 5.5</td>
</tr>
<tr>
<td>SD</td>
<td>26.5/14.0</td>
<td>37.0/14.2</td>
<td>13.8/7.3</td>
</tr>
</tbody>
</table>

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Correlation with Height of Blood Pressure

In both groups a negative correlation was found between the auscultatory-intraarterial systolic BP and the height of systolic arm BP (fig. 2), i.e., the measure artifact increased with increasing pressure. No significant correlation was observed between the measure artifact and the height of diastolic BP (fig. 2). The hypertensives were divided into three groups according to the height of the intraarterial SBP (table 3). In all groups, auscultatory DBP was about 10 mm Hg above the intraarterial DBP and the scatter of the readings was nearly equal, although the smallest range of DBP readings was found in the group with lowest SBP.

Correlation to Arm Circumference

In both groups, a slightly positive, but statistically insignificant, correlation was observed between arm circumference and the measure artifact of both SBP and DBP (fig. 3).

Figure 1. Difference between auscultatory and intraarterial arm blood pressure in 59 hypertensive subjects with arm circumferences less than 35 cm and 52 obese subjects with arm circumference more than 35 cm. (S = systolic BP; D V = diastolic BP; auscultatory BP measured at Phase V).

Figure 2. The measure artifact (i.e., auscultatory-intraarterial blood pressure) in relation to level of blood pressure in 59 hypertensive subjects (left) and 52 obese subjects (right).
TABLE 3. Difference between Auscultatory and Intraarterial BP in 59 Hypertensive Subjects Divided into Three Groups According to Intraarterial SBP

<table>
<thead>
<tr>
<th>SBP (mm Hg)</th>
<th>Auscultatory/Intraarterial BP</th>
<th>Diastolic (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;160 (n = 18)</td>
<td>Mean: −3.1, SD: 7.4, Range: −20/ +9</td>
<td>Mean: +10.7, SD: 4.8, Range: +4/ +20</td>
</tr>
</tbody>
</table>

FIGURE 3. The measure artifact (i.e., auscultatory-intraarterial blood pressure) in relation to arm circumference in 59 hypertensive subjects (left) and 52 obese subjects (right).
Correlation to Age

No correlation between age and the measure artifact of either SBP or DBP could be demonstrated in the hypertensive or obese group. The hypertensives were divided according to age into three groups. As seen in table 4, there was no substantial difference between the measure artifact of the groups but, it should be mentioned that most of the patients were between 50 and 59 years old, and only 11 were 60 years or older.

Correlation to Antihypertensive Medication

In the hypertensive group, 56 of the 59 patients were on antihypertensive medication at the time of investigation. The medication varied considerably, however, and it was not possible to collect pure groups on different medications.

Discussion

The present study showed, on the average, good agreement between auscultatory and intraarterial BP measurements, among the hypertensive subjects and obese subjects; auscultatory SBP was a few mm Hg below intraarterial SBP, while auscultatory DBP Phase V was on the average a few mm Hg above the intraarterial DBP. This corresponds to previous studies of several authors (table 5). We have not included measurements of DBP Phase IV as we found it well established from earlier investigations that DBP Phase IV gave DBP readings too high compared to intraarterial values. As mentioned in the introduction, in the previous studies other than that of Donde et al., only a few of the patients were hypertensive. It is interesting that the SBP measure artifact increased

<table>
<thead>
<tr>
<th>Authors</th>
<th>No. of subjects</th>
<th>Age (yrs)</th>
<th>Patients investigated</th>
<th>Number treated or untreated hypertensive</th>
<th>Auscultatory/Intraarterial BP</th>
<th>Average difference and range (or SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ragan &amp; Bordley (1941) (ref. 1)</td>
<td>40 adults</td>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td>SBP (mm Hg) DBP (Phase IV) DBP (Phase V)</td>
</tr>
<tr>
<td>Roberts &amp; al. (1953) (ref. 2)</td>
<td>47 &gt;70</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td>+0.4 -21/+40 7/+30</td>
</tr>
<tr>
<td>Henschel &amp; al. (1954) (ref. 3)</td>
<td>11 21-28</td>
<td></td>
<td>Young normotensive men</td>
<td>None</td>
<td></td>
<td>-12.3 (SD = 14.2) -2.4*</td>
</tr>
<tr>
<td>Van Bergen &amp; al. (1954) (ref. 4)</td>
<td>70 3-82</td>
<td></td>
<td>Surgery patients in general anesthesia</td>
<td>“Many of the patients were hypertensive”</td>
<td></td>
<td>-4 8 5</td>
</tr>
<tr>
<td>Godden &amp; al. (1955) (ref. 5)</td>
<td>35 —</td>
<td>Healthy young adults</td>
<td>None</td>
<td>-9.7 +7.3</td>
<td>-30/+18 -20/+31</td>
<td></td>
</tr>
<tr>
<td>Imhof &amp; Hürlimann (1958) (ref. 6)</td>
<td>40 19-80</td>
<td>Healthy adults</td>
<td>about 10</td>
<td>-0.4 +10.9</td>
<td>-13/+10 -4/+29</td>
<td></td>
</tr>
<tr>
<td>Karvenen &amp; al. (1964) (ref. 7)</td>
<td>53 &lt;20-61</td>
<td>Postoperative invest. of different surgical patients</td>
<td>SBP&gt;160/18 DBP&gt;100/10</td>
<td>+0.5 +17.7 +7.6</td>
<td>SD = 12.3 SD = 15.1 SD = 14.4</td>
<td></td>
</tr>
<tr>
<td>Holland &amp; Hummerfelt (1964) (ref. 8)</td>
<td>47 10-69</td>
<td>Different patients and staff members</td>
<td>SBP&gt;160/18 DBP&gt;100/9</td>
<td>-24.5 -5.3 +13.1</td>
<td>SD = 12.3 SD = 15.1 SD = 14.4</td>
<td></td>
</tr>
<tr>
<td>Simpson &amp; al. (1965) (ref. 9)</td>
<td>24 23-66</td>
<td>Different patients and staff members</td>
<td>SBP&gt;160/4 DBP&gt;100/1</td>
<td>-3.7 +1.7</td>
<td>SD = 5.7 SD = 8.1</td>
<td></td>
</tr>
<tr>
<td>King (1967) (ref. 10)</td>
<td>25 —</td>
<td>Normotensive young men</td>
<td>cuff 13 x 26</td>
<td>-4.4 +12.6</td>
<td>-30/+40 -1/+30</td>
<td></td>
</tr>
<tr>
<td>Raftery &amp; Ward (1968) (ref. 11)</td>
<td>50 18-44</td>
<td>Pregnant, normotensive women</td>
<td>None</td>
<td>-5.4 +6.6</td>
<td>-29/+18 -7/+29 -13/+26</td>
<td></td>
</tr>
<tr>
<td>Forsberg &amp; al. (1970) (ref. 12)</td>
<td>52 18-83</td>
<td>Different patients</td>
<td>18 hypertensive (12 nonobese, 6 obese)</td>
<td>+4 15</td>
<td>SD = 12.1 SD = 9.7</td>
<td></td>
</tr>
<tr>
<td>Donde &amp; al. (1974) (ref. 13)</td>
<td>104</td>
<td>Normotensive and hypertensive adults</td>
<td>&gt;160 and/or &gt;100/55</td>
<td>-12.0 +13.0</td>
<td>-70/+48 -14/+36</td>
<td></td>
</tr>
</tbody>
</table>

*Six patients with DBP (Phase V) = 0 are not included in the calculation.
†Range read from figures in the article.
with increasing BP, a finding also observed by other authors.\textsuperscript{6,8,11,13} This seems to be explained not by the inability to record the first audible Korotkoff sound, but by the increasing "critical closing pressure" with the increasing level of blood pressure.\textsuperscript{16}

The divergence from the study published by Holland and Humerfelt\textsuperscript{6} is hard to explain, as contrary to all other studies, these authors found intraarterial BP values much higher than both systolic and diastolic auscultatory BP, but could not explain this divergence.

In all previous studies, as in ours, considerable interindividual differences were observed with a wide scatter of the measure artifact. It is important to stress that the measure artifact cannot be predicted in the single patient from age, height of blood pressure, or arm circumference.

The occluding cuffs used by us should be discussed further. For the hypertensive subjects with an arm circumference less than 35 cm, the balloon used was 12 cm in width and 35 cm in length, in accordance with the previous recommendation from American Heart Association\textsuperscript{17} i.e., the width of the cuff was equal to 120\% of the diameter of the extremity. In 1980 the AHA Committee still recommended\textsuperscript{18} a bladder length twice the width of the cuff. Karvonen et al.\textsuperscript{7} and Simpson et al.\textsuperscript{9} argued earlier that interindividual differences seemed to be reduced if a 35-cm long cuff was used in normal adults. The present study showed that, even with a 35-cm long cuff, the interindividual variation is still considerable.

For the obese subjects we used a 15 × 43 cm cuff. It is important to stress that, if a 12-cm cuff is used for obese subjects, over estimation of arm blood pressure (cuff hypertension) may occur.\textsuperscript{5} Our study shows a similar average difference and interindividual scatter in the hypertensive group, with a normal dimension of the upper arm, compared with the data for the obese group where a wider cuff was used. We therefore recommend a 15-cm cuff for obese subjects with an arm circumference exceeding 35 cm. The last AHA recommendation\textsuperscript{18} was for a 17-cm cuff in large adults with arm circumferences between 32 and 42 cm, and even a 20-cm (thigh) cuff in the extreme when the circumference is over 42 cm. We tried to use wide cuffs in the obese group according to the 120\% rule, but had to give up as it was nearly impossible to place such wide cuffs around the upper arm because of the conic shape and the often short length of the upper arm. We find the commercially available 15 × 43 cm cuff most suitable in this group where hypertension is often suspected.

From the present results it might seem desirable to compare auscultatory and intraarterial BP measurements in all the hypertensive subjects. However, the comparison is time-consuming and may be painful for some patients, even if local anesthesia is used. Furthermore, technical equipment and technicians are needed. Therefore it cannot be recommended that evaluation of the measure artifact be performed for all patients. We are now using the measurements from subjects whose hypertension is poorly controlled, in order to establish whether the measure artifact exceeds the average findings of the present investigation. If a gross overestimation of the intraarterial DBP results, we recommend taking this finding into account when antihypertensive medication is titrated.

References

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