A proposed algorithm for diagnosing hypertension using automated office blood pressure measurement

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Objective To validate an algorithm for the interpretation of automated office blood pressure (AOBP) measurement based upon data from untreated patients referred by physicians in the community for 24-h ambulatory blood pressure monitoring (ABPM).

Methods An algorithm for interpreting AOBP readings was developed taking into account the previously documented equivalence of AOBP and mean awake ambulatory BP (ABP; mmHg), which were each classified as optimum BP (<130/80), borderline BP (130–139/80–89) and hypertension (≥140/90). This classification was applied to data derived from 254 untreated patients undergoing 24-h ABPM, AOBP and routine manual BP taken at the patient’s own physician’s office.

Results The mean awake ABP (135.3 ± 12.4/81.0 ± 10.2) was similar to the mean AOBP (132.6 ± 17.4/80.0 ± 11.1) with both values being significantly (P < 0.001) lower than the routine manual BP (149.7 ± 15.2/89.3 ± 9.5). Of the 69 patients with a systolic AOBP at least 140, only five (7.3%) exhibited white-coat hypertension with a normal mean awake ambulatory systolic BP less than 130. Similarly, of the 47 patients with a diastolic AOBP at least 90, none had optimum BP (diastolic BP < 80 mmHg on ABPM). White-coat hypertension was significantly (P = 0.005/P = 0.006) more prevalent for systolic/diastolic BP (22.1%/13.4%) when routine, manual BP readings were analysed.

Conclusion In contrast to routine manual office BP, a diagnosis of hypertension by AOBP is unlikely to be associated with an optimum awake ABP. J Hypertens 28:703–708 © 2010 Wolters Kluwer Health | Lippincott Williams & Wilkins.

Introduction

Automated measurement of blood pressure (BP) in the office represents a shift in the paradigm away from conventional manual BP recordings. Two recent developments in automated sphygmomanometer technology will likely soon change how BP is measured in routine clinical practice.

The first development is the availability of fully automated, BP recording devices, which meet validation standards for accuracy and reliability independent of the manufacturer [1–3]. The second development is the accumulation of evidence that automated office blood pressure (AOBP) measurement with patients resting alone in a quiet examining room can virtually eliminate the white-coat response generally associated with conventional manual sphygmomanometry [4,5]. The key to reducing the white-coat response appears to be multiple BP readings taken in the absence of the health professional in the room, thus eliminating patient–observer interaction, which seems to be a major factor in provoking office-induced increases in BP.

During the past few years, two devices have been specifically marketed for AOBP, the BpTRU and the Omron HEM 907. These devices were designed to improve upon the accuracy and reliability of conventional manual BP by reducing the white-coat response associated with office BP measurement. In Canada, about 10 000 BpTRU units are currently in use in clinical practice (BpTRU Medical Devices Ltd., Coquitlam, British Columbia, Canada, personal communication) in the absence of specific guidelines on how to interpret appropriately the BP readings that these devices generate.

In two large studies [4,5], AOBP has been shown to virtually eliminate the white-coat response associated with conventional office BP readings, resulting in similar values for the AOBP and the mean awake ambulatory (A) BP, a gold standard for determining cardiovascular risk associated with BP status. The individual AOBP readings also showed a significantly higher correlation with the mean awake ABP in comparison to BP readings recorded in routine clinical practice.
These two studies included relatively unselected patients with treated hypertension residing in the community [4] and both treated and untreated patients referred by their family physicians to an ambulatory blood pressure monitoring (ABPM) unit at our centre for assessment of 24-h BP status [5]. The latter population is of special interest, as ABPM would have been frequently requested because of uncertainty about the accuracy of the conventional office BP in evaluating BP status.

To date, there have not been any guidelines to assist in the appropriate interpretation of AOBP readings obtained with the patient alone in the examining room. The close relationship between AOBP and awake ABP introduces the possibility that AOBP can be used to diagnose optimum BP and hypertension without needing to perform 24-h ABPM, similar to what has been proposed for a home BP measurement [6]. In the present study, recent American Heart Association guidelines for interpreting ABPM [7] have been adapted to classify the BP status of patients in an algorithm (Fig. 1), which integrates AOBP into the diagnosis of hypertension. In accordance with these guidelines, the algorithm defines the awake ABP (mmHg) as optimum (<130/80), borderline (130–139/80–89) and hypertensive (>140/90).

In order to validate the application of these guidelines for routine clinical practice, AOBP recorded with the patient alone and routine manual BP readings taken by the patients’ own family physicians have been analysed using the proposed algorithm to determine if AOBP can more accurately classify office BP compared with the routine manual BP.

**Methods**

**Patient population**

AOBP readings taken with the patients resting alone in a quiet examining room were recorded in 254 consecutive, untreated patients referred for 24-h ABPM by their family physicians. Information obtained on each patient included the last routine manual BP taken by the patients’ own family physician at the time of referral for ABPM, age, sex and any medications potentially affecting BP. The study was approved by the Institutional Review Board at Sunnybrook Health Sciences Centre and written informed consent was not required, adding a ‘real world’ component to the ABPM and AOBP recordings.

**Procedures**

Details of the procedures followed have been previously published [5]. All patients had a series of five readings taken using a BpTRU model 100 device while they were resting alone in a quiet examining room in the ABPM unit. The device was set to record BP at one or two minute intervals (timed from the start of one reading to the start of the next reading). There was no standardized period of rest before each set of BP measurements. A mean of the five consecutive AOBP readings was automatically computed by the BpTRU recorder.

Each patient then underwent 24-h ABPM using a SpaceLabs model 90207 automated recorder (SpaceLabs Healthcare Ltd, Issaquah, Washington, USA). Patients were instructed to conduct routine daily activities during this period. The ABP recorder was set to take readings every 15 min from 0800 to 2200 h and at 30 min intervals during the night. Mean awake ABP was then calculated according to the actual awake period recorded in the diary submitted by each patient.

**Statistical analysis**

Mean ± SD was calculated for the five AOBP readings taken with the BpTRU device and for the mean awake ABP recording using the SpaceLabs 90207 monitor. Awake ambulatory readings were compared with the AOBP readings and the manual BP readings using Bland–Altman plots [8]. Bias from zero difference was determined as mean difference with 95% confidence intervals (CIs). The mean awake ABP was used as a reference standard and set at three levels: optimum BP (<130 or <80), hypertensive (≥140 or >90), and borderline BP (130–139 or 80–89). Similar cut-points were used to classify the AOBP and routine family physicians’ BP readings. The prevalence of white-coat hypertension based upon these categories for ABPM was computed for the AOBP and for the last routine manual BP reading taken by the patients’ own family physicians prior to referral to the ABPM unit and compared statistically using chi-squared test (systolic BP) and Fisher’s exact test (diastolic BP).

**Results**

AOBP readings and 24-h ABPM data were obtained in 254 patients consisting of 121 men and 133 women with mean age of 56.8 ± 15.1 years. The mean awake ABP...
(135.3 ± 12.4/81.0 ± 10.2) was similar to the mean of five automated office BP readings (132.6 ± 17.4/80.0 ± 11.1) taken using the BpTRU device with the patient resting alone in a quiet examining room in the ABPM unit. In contrast, the mean BP recorded by the patient’s own family physician at the time of referral for 24-h ABPM (149.7 ± 13.2/89.3 ± 9.5) was significantly \((P < 0.001)\) higher than with the mean awake ABP or mean AOBP.

The relationship between awake ABP and office BP readings (AOBP and family physicians’ manual BP) was examined using Bland–Altman plots (Fig. 2). There was a positive bias for the mean (95% CI) manual systolic reading of 14.4 (12.5–16.3) and manual diastolic reading of 8.3 (7.0–9.5) mmHg. In contrast, the mean difference for AOBP readings for systolic BP and diastolic BP was only −2.8 (−4.4 to −1.1) and −1.1 (−0.1 to −2.0) mmHg, respectively. Manual BP readings showed a positive bias throughout the entire BP range. The readings also exhibited ‘digit preference’ with systolic and diastolic BP ending in zero in 154 (61%) and 143 (56%) patients, respectively.

As might be anticipated, the majority of patients referred for 24-h ABPM had high systolic \((r = 204)\) or diastolic \((r = 157)\) BP readings in the family physicians’ offices (Table 1). After AOBP readings were taken, systolic and diastolic BP were high \((≥140 \text{ or } ≥90 \text{ mmHg})\) in only 69 and 47 patients, respectively.

If an optimum ABP is defined as systolic BP less than 130 mmHg and diastolic BP less than 80 mmHg, then only five of 69 patients with a systolic BP at least 140 mmHg using the automated BpTRU device would have been categorized as having white-coat hypertension with an ABP less than 130 mmHg (Fig. 2). Similarly, no patient with a diastolic BP ≥ 90 mmHg using the BpTRU recorder had an ABP less than 80 mmHg. white-coat

**Fig. 2**

Bland–Altman [10] plots are displayed for awake ABP versus routine manual physicians’ systolic (a) and diastolic (b) BP and for awake ABP versus automated office systolic (c) and diastolic (d) BP. The average of the ABP and manual BP (a and b) or automated BP (c and d) is plotted on the X-axis with the difference between the readings plotted on the Y-axis. Upper and lower limits of two standard deviations around the mean difference are indicated on each graph. ABP, ambulatory blood pressure; BP, blood pressure.
hypertension for systolic/diastolic BP was significantly ($P=0.005/P=0.006$) more prevalent with the family physician’s reading versus the AOBP (Fig. 3). For the optimum ambulatory systolic BP ($<130$ mmHg), white-coat hypertension occurred in 22.1% of patients. Similarly, for ambulatory diastolic BP less than 80 mmHg, white-coat hypertension was seen in 13.4% of patients using the family physician’s readings. Borderline AOBP systolic (130–139) and diastolic (80–89) values were present at 60 and 84 patients respectively (Table 1). The remaining patients had optimum systolic ($n=125$) and diastolic ($n=123$) AOBP readings.

**Discussion**

Previous comparisons between the mean awake ABP and AOBP with patients alone in the examining room have shown similar values for both measurement techniques (4.5). In the present study, various cut-points for AOBP in diagnosing optimum BP, borderline BP and hypertension were adapted from American Heart Association guidelines for ABPM [7] with AOBP readings evaluated in relation to the awake ABP. The findings support a pragmatic diagnostic algorithm for interpreting AOBP readings with patients alone in the examining room. More than 90% of patients with a single set of AOBP readings at least 140/90 had a diagnosis of hypertension based upon ABPM. The values for optimum AOBP ($<130/80$), borderline AOBP (130–139/80–89) and hypertensive AOBP (≥140/90) correspond to awake ABP readings for optimal BP ($<130/80$), normal BP ($<135/85$) and hypertension (≥140/90) recommended by hypertension guidelines [7,9]. In the case of AOBP, a ‘borderline’ BP range is recommended in order to facilitate incorporation of the findings into an algorithm suitable for routine clinical practice yet one that is based on ABPM cardiovascular outcome data. Similar approaches have been used to establish algorithms for interpreting manual office BP measurements [7,10–12].

Normal values for 24-h ABPM were initially defined on the basis of consensus opinion [11]. Analysis of different data sets led to a variety of cut-points defining normal versus high BP. In the PAMELA Study, Mancia et al. [13] reported a highly significant ($P<0.001$) relationship between clinic, home, 24-h and mean awake ABP readings. Upper limits for normal, home and ABP were derived from comparisons with clinic BP of 140/90 mmHg. Other investigators relied on mean ± two SDs to determine the upper and lower limits for high versus normal BP [14]. Yet a third method was to look at the 95th percentile to determine the upper limit of normal BP [15].

Using both comparative data and the limited cardiovascular outcome data available as of 1995, Pickering et al. [9] defined three levels of awake ABP: probably normal ($<135$ and $<85$) borderline (135–140/85–90) probably abnormal ($>140/90$). It was not until cardiovascular outcome data based upon 24-h ABPM became available that a consensus developed as to what constituted a normal BP versus hypertension based upon 24-h, mean awake or night-time BP readings with a cut-point of 135/85 mmHg considered, as the dividing line between normal awake ABP and hypertension [16,17].

More recently, nocturnal BP recorded with ABPM has been recognized as the best predictor of future cardiovascular events. In a meta-analysis of several clinical outcome studies, Fagard et al. [18] have reported a stronger relationship between future cardiovascular

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**Table 1 Patients (n = 254) are classified according to optimum BP, borderline BP and hypertension for automated office BP and family physician’s manual office BP readings**

<table>
<thead>
<tr>
<th>Classification of BP status</th>
<th>Systolic BP</th>
<th>Automated office systolic BP</th>
<th>Manual office systolic BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum</td>
<td>&lt;130</td>
<td>125 (49)</td>
<td>11 (4)</td>
</tr>
<tr>
<td>Borderline</td>
<td>130–139</td>
<td>60 (24)</td>
<td>39 (15)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>≥140</td>
<td>69 (27)</td>
<td>204 (80)</td>
</tr>
</tbody>
</table>

The percentage of patients in each category is shown in parentheses. BP, blood pressure.

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**Fig. 3**

![Diagram](https://via.placeholder.com/150)

The number (%) of patients with white-coat hypertension (awake ABP <130/80 mmHg) are shown for automated office (AO) BP and routine family physician (FP) BP readings. Significant differences between AOBP and FPBP readings are shown (∗$P=0.006$; **$P=0.008$): AOBP, ambulatory blood pressure; BP, blood pressure.
events and night-time or 24-h ABP compared with mean awake ABP. However, all three measures of ABP are closely related and all predict cardiovascular morbidity and mortality significantly better than does the office BP. Historically, white-coat hypertension has been defined in terms of the awake ABP, presumably because patients are also awake for office readings. However, the interpretation of the results of 24-h ABPM should also take into account the 24-h and night-time readings, as recommended by guidelines for implementing ABPM into clinical practice.

To date, a mean awake ABP and home BP less than 135/85 mmHg are still considered to be normal, although the most recent analysis of data from several studies by the International Database on Ambulatory blood pressure and Cardiovascular Outcomes (IDACO) group [19] and others [20] suggest lowering the cut-point for mean awake ABP to 130/85 or even 130/80 mmHg.

Many of the patients in the present study would be expected to exhibit a white-coat response, as they were referred for 24-h ABPM. In defining hypertension based upon office and ABPM, the mean awake ABP was selected as a gold standard for BP-related cardiovascular clinical outcomes. Virtually all previous studies of white-coat hypertension compared the office/clinic BP with the mean awake BP, as was done in the present study.

Recent concerns about conventional office BP being a relatively poor predictor of cardiovascular risk have led some advocates of ABPM and home BP to suggest that office BP measurement be abandoned altogether [21]. The ascertainment of a close concordance between AOBP and the mean awake ABP could re-establish reliance on office BP readings in order to optimally diagnose and manage hypertensive patients in primary care settings [4,5]. In addition to the findings in the present study providing a basis for diagnosing hypertension, other recent reports [4] have shown a significantly higher correlation between awake ambulatory and AOBP in comparison with routine office BP in the community. Moreover, AOBP is more consistent than manual BP under different conditions with mean values being similar both inside and away from the physician’s office and from one office visit to the next [22].

Figure 1 shows how AOBP could be incorporated into an algorithm for diagnosing hypertension in untreated patients. Based upon the current data, patients with AOBP less than 130/80 mmHg can be classified as having an ‘optimum’ BP. Unless, other factors such as high cardiovascular risk or suspected masked hypertension are present, these individuals can be followed with AOBP. Any trend toward higher AOBP readings may require 24-h ABPM to obtain a more precise measure of BP status and future cardiovascular risk.

Patients with an AOBP at least 140/90 mmHg generally have a diagnosis of hypertension and will usually require lifestyle modification and/or drug therapy. Based upon the data in the present study, the remaining one-quarter to one-third of patients with borderline BP values should undergo further assessment with 24-h ABPM, if available, especially if multiple cardiovascular risk factors or target organ damage are present.

Although not addressed in this study, the mean awake ABP, AOBP and home BP appear to be comparable. Thus, it might be possible to substitute home BP for AOBP in the proposed algorithm. Alternatively, patients may be classified for BP status using both AOBP and home BP, especially if 24-h ABPM is not available.

Bland–Altman plots of the individual BP readings showed a consistent white-coat response over the entire range of BP values when manual BP was compared with the awake ABP (Fig. 2). In contrast, a similar analysis of data for the AOBP did not show any significant white-coat response with the dispersion of individual AOBP readings above and below zero difference being similar in both the normotensive and hypertensive BP range.

The present study has several potential limitations. There are currently no data on differences between ABP and AOBP in the general population. In the present study, patients were referred for 24-h ABPM and do not represent a random sample of residents in the community or hypertension population. However, patients with a suspected white-coat response are the group of greatest interest when it comes to ascertaining more precisely an individual’s BP status. It is likely that all hypertensive patients might potentially benefit from the approach to AOBP measurement as outlined in this paper.

In all comparisons of AOBP with ABPM, only a single set of AOBP readings from one visit has been used for the office value. In clinical practice, patients with borderline hypertension would generally have BP recorded during multiple visits to the physician’s office. Thus, it is likely that BP status may be defined more precisely with repeat AOBP readings without needing to resort to out-of-office BP measurements.

The BP readings taken at the family doctor’s office prior to referral for ABPM were not verified as part of the research study. Also, the family physicians measured the patients’ BP in the usual way with no special attempt being made to obtain a ‘research quality’ reading. However, both of these aspects of the study were considered essential in order to assess the status of each patient under ‘real-world’ conditions. If the patients’ physicians had been told that the readings were being used for research purposes, the Hawthorne effect would have come into play leading to better quality readings being
taken as demonstrated in a previous study from our centre [23]. The intention of the present study was to examine the diagnosis of hypertension, as it is actually being made in routine clinical practice and not in an artificial setting as part of a tightly controlled research study. The intended result was clearly achieved in that 61 and 56% of the systolic and diastolic readings, respectively, taken in the family physicians’ offices exhibited ‘digit preference’ by ending in zero.

Finally, the algorithm is based upon the close relationship between AOBP and the awake ABP. There are currently no clinical outcome studies on AOBP to support the algorithm.

In summary, AOBP with the patient resting alone in a quiet room provides an opportunity to measure BP in the office in routine clinical practice with readings comparable to the mean awake ABP. Diagnosis of both hypertension and normal BP status can be made with a high degree of certainty using cut-points of 140/90 and 130/80, respectively. Patients with intermediate BP values may require further assessment such as 24-h ABPM or possibly multiple home BP measurements in accordance with recently published guidelines.

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There are no conflicts of interest.

References


