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Review Article

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Automated Office Blood Pressure Measurement

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ABSTRACT

Manual blood pressure (BP) recorded in routine clinical practice is relatively inaccurate and associated with higher readings compared to BP measured in research studies in accordance with standardized measurement guidelines. The increase in routine office BP is the result of several factors, especially the presence of office staff, which tends to make patients nervous and also allows for conversation to occur. With the disappearance of the mercury sphygmomanometer because of environmental concerns, there is greater use of oscillometric BP recorders, both in the office setting and elsewhere. Although oscillometric devices may reduce some aspects of observer BP measurement error in the clinical setting, they are still associated with higher BP readings, known as white coat hypertension (for diagnosis) or white coat effect (with treated hypertension). Now that fully automated sphygmomanometers are available which are capable of recording several readings with the patient resting quietly, there is no longer any need to have office staff present when BP is being recorded. Such readings are called automated office blood pressure (AOBP) and they are both more accurate than conventional manual office BP and not associated with the white coat phenomena. AOBP readings are also similar to the awake ambulatory BP and home BP, both of which are relatively good predictors of cardiovascular risk. The available evidence suggests that AOBP should now replace manual or electronic office BP readings when screening patients for hypertension and also after antihypertensive drug therapy is initiated.

Keywords: Blood pressure; Hypertension diagnosis; Measurement; Devices; Office

THE ORIGINS OF AUTOMATED OFFICE BLOOD PRESSURE (AOBP) MEASUREMENT

Problems associated with manual blood pressure (BP) measurement in the office setting have been known for several decades. Actions such as talking with the patient, not allowing for a period of rest before the readings, rapid deflation of the cuff and rounding off readings to the nearest zero have resulted in readings which are both inaccurate and inappropriately high. The publication of guidelines on the proper measurement of BP by various organizations may have increased awareness of these problems on the part of health professionals, but did little to correct them. Manual office BP was considered to be the

standard measure of an individual's BP status, based upon the use of this technique in most research studies. What almost everyone failed to appreciate were the clinical implications of the differences between BP as recorded in research studies compared to readings obtained in routine clinical practice.

Once our centre started using 24-hour ambulatory blood pressure monitoring (ABPM) for patient care in 1985, it became evident that office readings were frequently much higher than the awake ambulatory blood pressure (ABP), in both untreated patients with suspected hypertension and in those individuals already receiving antihypertensive drug therapy. These observations led to a study involving 147 hypertensive patients being treated by 6 family physicians in the community.[1] Study participants had their BP recorded in several ways, including by a research nurse and by 24-hour ABPM. The BP reading in their medical files taken during the last routine office visit was also noted. The most striking finding was that the mean routine office visit BP (146/87 mmHg) was much higher than both the study nurse's research reading (137/78 mmHg) and the awake ABP (132/78 mmHg).

The different readings were also correlated with left ventricular mass as determined by echocardiography.[1] This measure of target organ disease related to hypertension correlated significantly ($p<0.01$) with the research nurses' BP ($r=0.23$) and awake ABP ($r=0.24$) but not with routine office BP reading ($r=0.06$). These results confirmed that manual office BP as recorded in routine clinical practice was associated with higher BP readings, known as a white coat effect (WCE), and also that the readings were not predictive of intermediate measures of target organ damage, such as left ventricular hypertrophy.

Several years later, we performed a simple study[2] to see if the WCE associated with office BP could be eliminated by having 27 patients record their own BP in duplicate using a semi-automated, oscillometric sphygmomanometer designed for taking home BP, while they were resting quietly and alone in an examining room. The results were considered to be negative in that the mean patients' self-measured BP (155/80 mmHg) was similar to their family doctor's reading recorded for the study (157/83 mmHg), with both values being higher than the mean awake ABP (145/78 mmHg). In retrospect, these results should not have been surprising, since involvement of the patient in activating the oscillometric sphygmomanometer twice to record the BP likely increased the reading. Also, having the family physician take a special BP for the study probably resulted in a lower, 'research quality' BP reading.

In 2002, 2 fully automated, osclillometric sphygmomanometers became available for professional use in the office setting, the BpTRU and the Omron 907. In 2003, we followed up our earlier study, this time by using the fully automated BpTRU to record BP in 22 hypertensive patients, while resting alone in an examining room.[3] Mean manual office BP was reduced from 174/92 to 155/88 mmHg when taken with the BpTRU, thus confirming that recording office BP automatically, without office staff being present, reduces the WCE. This study established the principles of what we later called AOBP measurement[4]: multiple BP readings recorded using a fully automated, oscillometric sphygmomanometer with the patient resting quietly and alone. Initially, alone meant in a separate examining room, but it was subsequently shown that AOBP could also be recorded in a community pharmacy,[5] a doctor's waiting room[6] or an ABPM unit,[7] as long as the patient was not disturbed and there was no opportunity for conversation.

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COMPARATIVE BP STUDIES INVOLVING AOBP

The implications of these findings were not fully appreciated until the publication in 2005 of an article by Beckett and Godwin[8] who obtained office BP readings in 481 treated hypertensive patients in family doctors' offices using the AOBP method, with the BpTRU device recording a mean of 5 readings with the patients resting quietly and alone. These investigators demonstrated the advantages of applying AOBP measurement to routine clinical practice by showing that the average of the last 3 routine manual office BP readings (151/83 mmHg) was reduced to 140/80 mmHg using AOBP, which was similar to the mean awake ABP of 142/80 mmHg. The awake systolic/diastolic ABP also correlated significantly more strongly with the AOBP (r=0.57/r=0.61) than with the routine office BP (r=0.14/r=0.32).

The findings of Beckett and Godwin[8] were confirmed in 309 patients referred for 24-hour ABPM with awake ABP being compared to both the last routine office BP recorded by the patient's own family doctor and to an AOBP reading.[9] Both the mean AOBP (132/75 mmHg) and the awake ABP (134/77 mmHg) were significantly ($p<0.001$) lower than the BP recorded in the family doctor's office (152/87 mmHg) during the last routine visit. Awake ABP also exhibited a significantly stronger correlation with the AOBP compared to the routine office BP.

Similar observations have now been made in relatively unselected hypertensive patients in family practice and in patients referred for 24-hour ABPM,[4][10] mostly to exclude white coat hypertension. However, such observational studies may be subject to a variety of biases, some obvious and others less so. The highest level of evidence to confirm the advantages of AOBP, a randomized controlled trial, is also the most difficult type of study to perform, especially in a 'real world' setting. Involvement in a research study virtually precludes the setting from being 'real world,' given the possibility that the subjects and researchers will alter their behaviour under these circumstances. Despite these concerns, we undertook a randomized, controlled trial to compare AOBP with manual office BP measurement during routine office visits in a family practice setting.

In the conventional versus automated measurement of blood pressure in the office (CAMBO) trial,[11] 88 primary care physicians in 67 practices in 5 cities in Eastern Canada were randomized to either using AOBP with a BpTRU device to measure BP in their hypertensive patients or to continue using manual office BP, as before. Physicians randomized to the AOBP technique were only instructed on the use of the device and those in the control, manual BP group were told to continue office BP measurement as they had always done. Nothing was said about antihypertensive therapy or other aspects of hypertension management. Randomization of the 555 patients with systolic hypertension was done by cluster (practice groups) to minimize the likelihood that physicians in the control group would be aware of the activities in the intervention AOBP group.

The results of the CAMBO trial confirmed the findings in the observational studies.[4][10] In the AOBP group, the mean manual BP of 150/81 mmHg during the last routine visit to the family physician's office decreased to 136/78 mmHg on the first routine office visit after enrollment in the study. However, in the control group, the mean manual BP pre-entry of 150/82 mmHg was also lower than the manual BP on the first office visit after enrollment (141/80 mmHg), despite the only instructions having been to perform office BP as before. Nonetheless, the primary endpoint in the study, the difference between the mean awake

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Table 1. Mean BP readings (mmHg) recorded in routine clinical practice and as part of a research study using standardized measurement guidelines

Author	Number of patients	Routine clinical practice BP (mmHg)	Research study BP (mmHg)
Myers et al.[1]	147	146/87	140/83
Brown et al.[12]	611	161/95	152/85
Graves et al.[13]	104	152/84	138/74
Gustavsen et al.[14]	420	165/104	156/100
Myers et al.[9]	309	152/87	140/80
Head et al.[15]	6,817	150/89	142/82
Burgess et al.[16]	150	145/85	132/79
Mean BP		153/90	143/83

BP = blood pressure.

ambulatory systolic blood pressure (SBP) and the office SBP at the first return visit was significantly (p=0.006) less (2.3 mmHg) in the AOBP group than in the control manual BP group (6.5 mmHg). It seems that, once in a research study, the office staff read the patients' manual BP lower. However, these manual BP readings were not more accurate, in that 50% were still rounded off to the nearest zero and they correlated relatively poorly with the awake ABP.

The next question to be addressed concerned the relationship between routine office BP and manual office BP as recorded in research studies in accordance with standardized guidelines. Data from 7 studies[1)9)12-16)] in 4 countries (**Table 1**) showed that the mean office BP in routine clinical practice of 153/90 mmHg corresponded to a mean office BP of 143/83 mmHg recorded in a research study. Although the threshold for defining hypertension based upon office BP has traditionally been 140/90 mmHg, a threshold of 150/97 mmHg might be more appropriate. Until recently, little attention has been given to this discrepancy, but it is now timely to consider alternatives to manual office BP measurement.

One option could be to simply replace mercury or aneroid sphygmomanometers with oscillometric devices, which have been used extensively in recent research studies. However, in a study[17)] in primary care in Spain, office BP readings recorded with an oscillometric sphygmomanometer in duplicate in the presence of office staff in over 27,000 hypertensive patients still exhibited a WCE, with the mean office BP being 160/89 mmHg compared to an awake ABP of 135/78 mmHg. Thus, simply replacing manual office BP with oscillometric office BP taken in the presence of office staff does not reduce WCE.

In contrast, mean AOBP recorded in a variety of settings[7-9)11)18-21)] in different populations (139/80 mmHg) was similar to the mean awake ABP (139/80 mmHg; **Table 2**). Unlike manual office BP, AOBP readings do not seem to be affected by the location of the patients, providing they are taken with a fully automated device with the patient resting quietly and alone.[5-7)]

Table 2. Studies comparing AOBP with awake ABP in different clinical settings

Author	Number of subjects	Patient population	AOBP (mmHg)	ABP (mmHg)
Myers et al.[9]	309	ABPM unit	132/75	134/77
Beckettand Godwin[8]	481	Family practice	140/80	142/80
Myers et al.[7]	62	Hypertension clinic	140/77	141/77
Myers[18]	254	ABPM unit	133/80	135/81
Godwin et al.[20]	654	Family practice	139/80	141/80
Myers et al.[19]	139	ABPM unit	141/82	142/81
Myers et al.[11]	303	Family practice	135/77	133/74
Andreadis et al.[21]	90	Hypertension clinic	140/88	136/87
Mean BP			138/80	138/80

ABP = ambulatory blood pressure; ABPM = ambulatory blood pressure monitoring; AOBP = automated office blood pressure; BP = blood pressure.

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Not only is the AOBP similar to the awake ABP, but also both mean AOBP and awake ABP are about 15/8 mmHg lower than office BP in routine clinical practice.[10] These observations have been reported in different populations and in different countries. Thus, comparative data from multiple studies support replacing manual or oscillometric office BP readings with AOBP in screening individuals for possible hypertension and for the management of treated hypertensive patients.

AOBP AND CARDIOVASCULAR END-POINTS

Not only does AOBP correlate better than routine office BP with the awake ABP, it also correlates better with intermediate measures of target organ damage. In one study[22] involving 176 healthy male volunteers, the intimal-media thickness of the carotid artery correlated significantly (p=0.023) with the AOBP but not with manual office BP (p=0.859). Similarly, in 90 patients attending a hypertension clinic,[21] routine BP recorded with an oscillometric sphygmomanometer correlated poorly (r=0.12) with the left ventricular mass index. In contrast, both AOBP readings and the awake ABP correlated (r=0.37) significantly (p<0.001) with this measure of target organ damage.

AOBP was used in a hypertension screening trial[23] in 39 Canadian communities involving 15,889 participants, entitled the Cardiovascular Health Awareness Program (CHAP). In this study, communities were randomly allocated to either control (n=19) or to an intervention program (n=20), which included screening for hypertension using AOBP. CHAP is the only study to have demonstrated that screening for hypertension (with AOBP) can significantly reduce cardiovascular outcomes, namely hospitalization for cardiovascular events.

Among 3,627 CHAP participants who were untreated for hypertension, there was a graded increased risk for fatal and non-fatal cardiovascular events during 4.9 years of follow-up from SBP measured using AOBP of 110–119 mmHg to ≥160 mmHg and from a diastolic BP of 60–69 to ≥90 mmHg.[24] A significant increase in cardiovascular risk occurred at an AOBP of 135–144/80–89 mmHg, which is consistent with a threshold of 135/85 mmHg when using AOBP to define hypertension.

AOBP was also recorded in 6,183 CHAP study participants who were taking antihypertensive medication.[25] On-treatment systolic AOBP in the range of 110–119 mmHg was associated with the lowest cardiovascular event rate during 4.6 years of follow-up. This finding is consistent with the significant reduction in cardiovascular risk observed with a SBP treatment target of 120 mmHg versus 140 mmHg in the Systolic Blood Pressure Intervention Trial (SPRINT),[26] which also used AOBP to measure BP.

These cardiovascular outcome data support a threshold of 135/85 mmHg when using AOBP to screen for hypertension or to follow patients already on antihypertensive therapy. This conclusion is supported by comparative studies which have shown that AOBP is similar to the awake ABP (**Table 2**), with both of these BP measurements being about 15/8 mmHg lower than BP recorded in routine clinical practice.[10] Home BP is also similar to the AOBP and awake ABP methods. In 139 hypertensive patients referred for 24-hour ABPM, mean home BP was 142/85 mmHg compared to an AOBP of 141/82 mmHg and an awake ABP of 142/81 mmHg.[19] Thus, AOBP, awake ABP and home BP share a similar threshold for diagnosing hypertension and for managing treated hypertensive patients during follow-up.

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AOBP AND THE 2017 AMERICAN HYPERTENSION GUIDELINES

In November 2017, the American College of Cardiology in collaboration with the American Heart Association and several other organizations published an update of the 2003 Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC VII) hypertension guidelines.[27] One of the most noteworthy and controversial aspects of this new report was defining hypertension as a BP ≥130/80 mmHg. Moreover, an office BP of 130/80 mmHg was equated with an awake ABP and home BP of 130/80 mmHg; whereas, office BP had previously been 5/5 mmHg higher than the threshold of 135/85 mmHg used to define hypertension, both using out-of-office BP and, more recently, AOBP.[28] Although the American College of Cardiology (ACC)/American Heart Association (AHA) report[27] contained 164 pages of text and 367 references, only 6 references related to office BP measurement, with a single reference mentioning the Canadian hypertension guidelines[28] which recommended AOBP as the preferred method for office BP measurement. Moreover, only 4 lines of text were devoted to AOBP, with the conclusion being that "there is a growing evidence base supporting the use of AOBP measurements" (for diagnosing hypertension).

Given the evidence supporting the use of 140/90 mmHg as a threshold for diagnosing hypertension in clinical practice, it is surprising that so little attention was paid to creating a lower threshold of 130/80 mmHg without evaluating the office BP measurement literature since 2003 in greater detail. Some of the authors[29] did publish a separate article supporting antihypertensive therapy for patients with an office BP ≥130/80 mmHg, if associated with an increased cardiovascular risk, but there was no justification for basing the diagnosis of hypertension on a manual office BP of 130/80 mmHg, especially when recorded in clinical practice. Data were also not presented to support having the same diagnostic threshold for conventional office BP, awake ABP.

In reality, there are virtually no data equating a manual BP of 130/80 mmHg in routine clinical practice with a similar reading using ABPM or home BP. Data from the Spanish ABPM registry,[17] show that a mean office BP of 131.5/81.0 mmHg based upon duplicate readings recorded with an oscillometric sphygmomanometer in routine clinical practice in 5,028 patients was equivalent to a daytime ABP of 125.9/75.6 mmHg. In contrast, in 6 studies[10][30] where the mean systolic AOBP was 132–133 mmHg, the overall mean AOBP reading of 133/76 mmHg was similar to the mean awake ABP (134/78 mmHg). Thus, in the absence of routine manual office BP and evidence that routine oscillometric office BP is increased by 5/5 mmHg at a threshold of 13/80 mmHg, there is still justification for using AOBP with the new lower threshold for defining hypertension.

The evidence-based 2016 Hypertension Canada guidelines[28] recommended AOBP as the preferred method for recording office BP in clinical practice. Use of manual BP was discouraged. Moreover, these guidelines adopted the findings in SPRINT[26] by lowering the target systolic AOBP to <120 mmHg for patients with an office SBP of ≥130 mmHg and a higher cardiovascular risk. Unlike the new American guidelines,[27] the Canadian recommendations continue to define hypertension as an office BP ≥140/90 mmHg. The decision by the American panel to re-define hypertension as an office BP ≥130/80 mmHg would appear to have been unnecessary, unless the objective was to provide more encouragement for one-half of the adult American population now deemed to be hypertensive to reduce their consumption of salt and to lose weight. Many critics will

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question the wisdom of labeling one half of the population as having a 'disease' which might shorten their life, when there is little evidence that treating such mild hypertension is beneficial and especially if a relatively inaccurate method of office BP measurement is being recommended for routine clinical practice.

There has been one population survey[31] examining the feasibility of adopting ABPM and home BP for diagnosing hypertension and AOBP for hypertension screening and management on drug therapy. A random sample of 774 Canadian primary care physicians was asked about which type of BP readings they used to diagnose hypertension and to manage treated hypertensive patients. Note that 24-hour ABPM and home BP were first included in the algorithm for diagnosing hypertension in 2005 and AOBP was first mentioned as an option for performing office BP in 2011. Manual BP measurement was still being used by 54% of physicians to screen for hypertension, but 39% were now using AOBP for this purpose. However, only 21% of physicians were using manual BP to diagnose hypertension, whereas 14% were using ABPM, 22% home BP and 30% AOBP. Follow-up of treated hypertensive patients was performed with AOBP by 54% of physicians. Cleary, more effort is needed to increase the use of ABPM for diagnosing hypertension, but the widespread adoption of AOBP into clinical practice was noteworthy.

PRACTICAL CONSIDERATIONS

The Canadian experience also provides an opportunity to examine the practical aspects of adopting AOBP into routine clinical practice. Unlike many innovations in medicine, AOBP use was a primary care phenomenon, with specialties such as cardiology and nephrology slow to change from manual BP measurement to AOBP. This development is consistent with family physicians being mostly responsible for hypertension care in Canada. The major objections from critics of AOBP have been related to practical issues as much as scientific ones.

AOBP requires a quiet place for the patient to be alone for 4–7 minutes and a fully automated, oscillometric sphygmomanometer to record readings without active involvement of the patient. Many hypertension specialists did not have more than one examining room and did not see the need to purchase a relatively expensive sphygmomanometer when they believed that their own BP readings were accurate. Even this author was surprised at the difference between his manual office SBP readings and the mean awake systolic ABP, which, in patients with severe systolic hypertension, often exceeded 40 mmHg.[32]

In reality, AOBP takes no longer than a proper manual office BP, if the 5 minutes of rest before duplicate measurements are taken into account. Also, a separate examining room or other quiet place in the office is needed for both a manual BP and AOBP. Finally, sphygmomanometers for recording AOBP such as the Omron 907XL and Microlife WatchBP Office are relatively more expensive (about US $500), but only one device attached to a portable stand can be used in several examining rooms. In August 2017, the company which manufactured the BpTRU in Canada for unknown reasons closed its doors. Although the BpTRU has been used in most of the research studies on AOBP, the other 2 devices have also recorded AOBP in clinical research and are equally capable of taking readings in clinical practice.

There is now some evidence[33][34] that home BP recorders which automatically take 2–3 readings after a single activation can be used to obtain an office BP which is close to an AOBP value, providing the patient activates the device while resting alone in a quiet place. However,

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these modified home BP recorders, although less expensive, may lack sufficient durability to withstand frequent use in the office setting. Also, comparative studies using these devices have generally involved subjects with high normal or mild hypertension. It is not known if a patient–activated AOBP will eliminate the WCE at higher levels of SBP as effectively as an AOBP taken with a fully automated device.

It is important to remember that the primary use of AOBP is to screen patients for possible hypertension, with the diagnosis being confirmed by 24-hour ABPM or by a proper set of home BP readings. Comparative BP data suggest that AOBP is still quite useful after drug therapy is initiated, but, as readings approach target, WCE becomes less of a concern. As long as the target BP was 140/90 mmHg, this was not an issue, but with lower targets, such as <120–130/80 mmHg, there may be little difference between AOBP and duplicate oscillometric BP readings, with AOBP readings possibly being too low, in comparison to the awake ABP.[35] With the anticipated changes in target BP, more research is needed to determine the best technique for recording office BP when systolic readings are <125 mmHg. It should be noted that there are no comparative data for routine manual office BP versus awake ABP in the target SBP range of <130 mmHg.

CONCLUSION

AOBP is recommended as the preferred method for office BP measurement in the evidence-based Canadian guidelines. Other guidelines such as the European Society of Hypertension/European Society of Cardiology,[36] U.S. Preventive Services Task Force[37] and the 2017 United States ACC/AHA Recommendations[27] have also recognized the advantages of AOBP over routine office BP. Guidelines panels seem reluctant to recommend AOBP because the devices to record AOBP are currently not widely available, even though these devices are not extraordinarily expensive to purchase. Moreover, it makes little sense to subject patients to over-diagnosis and possible over-treatment of hypertension because of increased costs which are not excessive compared to other health care expenditures. Considering the current trend toward recording office BP with oscillometric devices, there is no reason to have office staff present when BP is being recorded, especially if the reading is being used to diagnose hypertension.

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