Correlation Between Ambulatory Blood Pressure Monitoring and Office Blood Pressure Measurement in Patients with Hypertension: A Community Study

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ABSTRACT

Background: The current gold standard for blood pressure (BP) measurements is based on office BP measurements (OBPMs) by a sphygmomanometer or a digital device. Ambulatory BP measurement (ABPM) is a noninvasive method for continuous monitoring of BP over a period during routine activities of the patient. Thus, ABPM offers multiple BP readings during the patients' daily routine as compared to the single reading by OBPM at rest. A good correlation exists between mean 24-hour BP readings and the prediction of cardiovascular events. The present multicenter observational study was aimed to assess the correlation between ABPM and OBPM in patients with newly diagnosed, controlled, or uncontrolled hypertension in the community setting.

Our hypothesis was to test if ABPM provides any further value in those hypertensive patients in whom the office blood pressure levels are controlled. A supplementary hypothesis was whether obtaining ABPM in patients with newly diagnosed or uncontrolled hypertension yields any value over and beyond OBPM. Another objective was to find out the applicability of ABPM in the community setting where the medical care is provided by primary care family physicians and not by specialists.

Materials and Methods: Materials and Methods A total of 1000 patients were analysed for this study. Those with controlled hypertension were assigned to Group A, and those with newly diagnosed/untreated hypertension comprised Group B. Group A was followed up during Visit 2 and Group B was followed up during Visit 2 and either Visit 3 or Visit 4 to assess the BP measurements by ABPM and OBPM.

Results: The correlation between ABPM and OBPM showed minimal variation in the BP readings of Group A subjects at Visit 2. A variation in BP readings was observed in Group B at Visit 2. Furthermore, the correlation was established between ABPM and OBPM noted for Group B subjects during Visit 3, and minimal variation was noted during Visit 4.

Conclusions: Conclusions A good correlation was observed between ABPM and OBPM during both visits in patients in Groups A and B. However, a notable variation was noted in the diastolic BP readings. Thus, large-scale clinical studies are required to detect the prevalence of hypertension, masked hypertension, and dipping patterns associated with hypertension and other related medical co-morbidities.

Keywords: India; Stroke; Hypertension; Ambulatory blood pressure measurement (ABPM); Office clood pressure measurement (OBPM). **[Am J Med Sci 2021;362(6):546–552.]**

INTRODUCTION

The current gold standard for measuring blood pressure (BP) is based on office blood pressure measurements (OBPMs) by a sphygmomanometer or by a digital device that measures both the systolic and diastolic BP in mmHg.[1] Ambulatory BP measurement (ABPM) is a non-invasive method for monitoring BP continuously for 24 hours during the routine activities of the patient and reflects real-time BP. Typically, ABPM readings are lower than those obtained in the clinical settings.[2]

According to the Framingham Heart Study, ABPMs correlate better with the target organ injury than

OBPMs.[3] Interestingly, ABPM offers multiple BP readings during various activities performed by the patient as compared to the single reading obtained by OBPM in the resting state of the patient. This is an advantageous feature of ABPM over OBPM. Although OBPM can indicate elevated BP, it fails to give a glimpse of nocturnal hypertension or variability in the BP. Conditions that warrant employing ABPM to measure BP are apparent drug resistance, suspected white-coat hypertension, hypotensive symptoms with antihypertensive medication, autonomic dysfunction, and episodic hypertension.[4]

Recent guidelines have highlighted the advantages of using ABPMs as compared to OBPMs. Another study established a correlation between mean 24-hour BP reading and prediction of cardiovascular events.[5] The National Institute of Health and Clinical Excellence (NICE, UK) recommended that ABPM should be considered as a cost-effective technique for all individuals suspected of hypertension.[6]

The present multicenter observational study aimed to assess the correlation between ABPM and OBPM in patients with newly diagnosed, controlled, and uncontrolled hypertension in the community clinical practice.

The setting in India is of significance because of high density of the population with increasing prevalence (30%) of hypertension. In a developing country, the use of emerging technologies (like ABPM) has a major role in controlling the cardiovascular risk factors. Most ABPM studies originated in the developed world and in the Indian context, this study offers unprecedented clinical value. Greater utility of ABPM will likely have a beneficial effect on public health policies for South Asia.

METHODS

The current study was approved by the Institutional Ethics Committees of the eight Apollo tertiary care hospitals in India (Ahmedabad, Bengaluru, Bhubaneswar, Chennai, Hyderabad, Madurai, New Delhi, and Visakhapatnam). A total of 1000 patients were analyzed for this study. Before the initiation of the study, the sites were trained thoroughly to handle the MedTech ABPM device.

Selection of study subjects

The potential patients were identified and screened according to the inclusion and exclusion criteria set by the clinical research team. The study subjects/legally authorized representatives (LARs) signed a voluntary informed consent form in order to facilitate the collection of necessary data from the hospital records. Inclusion Criteria: The patients with controlled hypertension were enrolled in Group A, and those with newly diagnosed/untreated hypertension were enrolled in Group B. ABPM was conducted in patients in both groups initially (Visit 1) to measure the basal level of hypertension. Exclusion Criteria: Pregnant women and subjects/LAR who were unable or refused to provide the consent were excluded from the study. Study did not direct the treatment plans which were entirely at the discretion of the physicians. This study was designed to evaluate the BP measurements in clinical practice, not to influence the therapeutic goals.

Group A study participants had a previous history of hypertension, and their blood pressure was under control as assessed by the treating doctor. Group B consisted of patients with newly diagnosed or uncontrolled hypertension. The hypothesis was to evaluate if ABPM provides any additional value in patients with hypertension whose blood pressure is well controlled in the office setting.

Data collection and blood pressure measurements

Group A patients visited the clinic for ABPM measurement one month after the initial visit. In the case of Group B, ABPM was carried out only when the BP was under control either during Visit 2 or 3 or 4 at monthly intervals. OBPM was measured for all patients before completion of ABPM. However, no changes were made in the routine clinical care of the patients. The relevant data were collected from the patients during each visit and recorded appropriately. The study data of 1000 evaluable patients with above 80% compliance with ABPM were utilized for further analysis.

RESULTS

Demographic details

A total of 1000 patients were enrolled, 500 in Group A and 500 in Group B. The subjects in Group A completed the study during Visit 2, whereas 216/500 subjects in Group B completed the study during Visit 2, 177 patients during Visit 3, and 107 at Visit 4.

Hypertension associated with medical comorbidities

Concomitant health conditions were distributed equally in Groups A and B. Patients had been diagnosed with only hypertension or hypertension with other co-morbid conditions such as dyslipidemia, diabetes, and coronary artery disease. Approximately 85% of the patient population was diagnosed with hypertension only, whereas the remaining presented co-morbid conditions (Table 1).

Medications usage for hypertension

The usual different classes of anti-hypertensive medication, including angiotensin converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARB), β-blockers, α-blockers, calcium channel blockers, diuretics, and other anti-hypertensive drugs, were prescribed. The Group A subjects were primarily treated with ARB, β-blockers, and Ca-channel blockers, and Group B subjects were prescribed ARB, β-blockers, and ARB + others (Table 2). It should be stated again that the study did not intervene with standard medical care of patients with hypertension.

Table 1. Percentage of patients associated with hypertension and other medical co-morbidities.

MEDICAL CONDITION	Group A		Group B	
	Number of patients	Percentage of total	Number of patients	Percentage of total
Total patients	500	100	500	100
Hypertension	429	85.8	430	89
Hypertension + Diabetes	37	7.4	37	7.4
Hypertension + Dyslipidemia	18	3.6	13	2.6
Hypertension + Diabetes + Dyslipidemia	7	1.4	10	2
Hypertension and others (Diabetes, Dyslipidemia, Heart disease)	9	1.8	10	2

Age and sex analysis

The distribution of male and female population in different age groups (18−75 years) was analyzed. The 40−70 years old group comprised 75% of the study population in Groups A and B. Strikingly, about 20% of the population between 20 and 40 years old had hypertension in both groups.

Group A: study completion at the end of one month visit 2

Mean BP: OBPMvs. ABPM (overall 24-hour): The correlation between ABPM and OBPM showed a minimal variation in the BP readings (Table 3). The average ABPM at Visit 1 was 125.4/75.2 mm Hg and the average OBPM was 125.7/79.5 mm Hg. During Visit 2, the ABPM and OBPM were 123.9/74.7 mm Hg and 124.9/78.6 mm Hg for ABPM and OBPM, respectively. Furthermore, the systolic and diastolic BP levels measured during Visit 1 and Visit 2 for both OBPM and ABPM were similar (Fig. 1). The mean BP measurements by OBPM and ABPM are represented in Table 3 and Fig. 1.

Group B: study completion at the end of one month visit 2

Mean BP: OBPMvs. ABPM (overall 24-hour): A variation in the BP readings was observed in Group B patients during Visit 2. The average ABPM during Visit 1 was 140.5/83.7 mm Hg as opposed to the average OBPM 142.9/87.4 mm Hg; the values during Visit 2 were 128.1/77.0 mm Hg and 124.6/77.2 mm Hg for ABPM and OBPM, respectively. Furthermore, the systolic and diastolic values varied during Visit 1 and Visit 2 for both OBPM and ABPM (Fig. 2). These variations indicate that ABPM is effective in monitoring the patients who are either newly diagnosed with hypertension or with

Table 2. Percentage of antihypertensive medications prescribed for Group 1 and Group 2.

Medication	Group A (%)	Group B (%)
ACE Inhibitor	3.9	6.87
ARB	28.7	16.74
β-blocker	13.6	13.3
α-blocker	1.4	0.43
Ca- channel blocker	13.6	8.15
Diuretic	1.4	7.3
ARB + Others	13.6	18
Others	6.1	7.7

Abbreviations: ACE, angiotensin converting enzyme; ARB, angiotensin receptor blockers.

Table 3. Group A - study completion details at end of Visit 2 (V1,V2) - OBPM and ABPM mean blood pressure measurements.

	Visit 1	End of study (V2)
	Blood Pressure (Sys/Dia)	
OBPM* Day 1	126.4/78.5	124.9/78.5
OBPM Day 2	125.0/80.4	125.0/78.7
OBPM average	125.7/79.5	124.9/78.6
ABPM** average	125.4/75.2	123.9/74.7
OBPM vs ABPM	*p*-value – Visit 1	End of Study
Systolic Blood Pressure	0.0081	0.0001
Diastolic Blood Pressure	< 0.0001	< 0.0001
ABPM Overall	Blood Pressure (Sys/Dia)	
Blood Pressure average	125.4/75.2	123.9/74.7
ABPM average daytime	128.7/78.1	127.2/78.0
ABPM average night time	117.4/69.2	116.2/68.3
Pulse/min	76.5	76.3
Double Product	9635.8	9571.1
ABPM Active Period		
Blood Pressure	128.7/78.1	127.2/78.0
Pulse/min	96.2	80.5
Double Product	10,366.6	10,327.1
ABPM Passive Period		
Blood Pressure	117.4/69.2	116.2/68.3
Pulse/min	69.4	68.7
Double Product	8213.7	8025.6

Abbreviations: ABPM, ambulatory blood pressure monitoring; OBPM, office blood pressure measurement.
* - Office blood pressure measurement.
** - Ambulatory blood pressure monitoring. *P* value – comparison of mean blood pressure differences between ABPM and OBPM, baseline versus end of study.

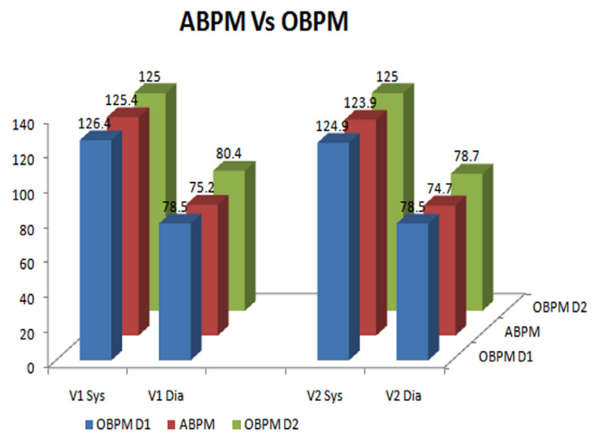

FIGURE 1. Group A - Overall OBPM and ABPM mean blood pressure measurements at the end of visit 2. Abbreviations: ABPM, ambulatory blood pressure monitoring; OBPM, office blood pressure measurement.

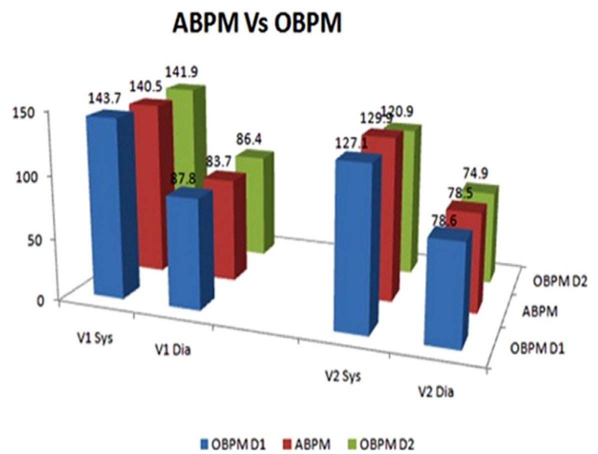

FIGURE 2. Group B - overall OBPM and ABPM mean blood pressure measurements at the end of Visit 2. Abbreviations: ABPM, ambulatory blood pressure monitoring; OBPM, office blood pressure measurement.

untreated hypertension. The mean BP measurements of OBPM and ABPM are represented in Table 4 and Fig. 2.

Table 4. Group B - study completion details at end of Visit 2 (V1,V2) - OBPM and ABPM mean blood pressure measurements.

	Visit 1	End of study
OBPM Day 1	143.8/88.0	127.5/78.9
OBPM Day 2	142.1/86.8	121.8/75.5
OBPM average	142.9/87.4	124.6/77.2
ABPM average	140.5/83.7	128.1/77.0
OBPM vs ABPM	*p*-value – Visit 1 & End of Study	
Systolic Blood Pressure	< 0.0001	< 0.0001
Diastolic Blood Pressure	< 0.0001	< 0.0001
ABPM Overall		
Mean Arterial Pressure	102.7	93.8
Double Product	11,040.5	9765.5
ABPM Active Period		
Blood Pressure	143.6/88.7	133.8/80.0
Mean Arterial Pressure	106	97.7
Double Product	11,750.8	10,799.3
ABPM Passive Period		
Blood Pressure	133.2/77.5	119.3/70.3
Mean Arterial Pressure	96.1	103
Double Product	9565.7	8277.8

Abbreviations: ABPM, ambulatory blood pressure monitoring; OBPM, office blood pressure measurement.
P value – comparison of mean blood pressure differences between ABPM and OBPM, baseline versus end of study.

Group B: study completion at the end of second month visit 3

Mean BP: OBPMvs. ABPM (overall 24-hour): A good correlation was established between ABPM and OBPM BP readings in Group B subjects during Visit 3. The average ABPM during Visit 1 was 141.6/84 mm Hg, and the average OBPM was 144.9/88.2 mm Hg; the values during Visit 3 were 128.7/77.9 mm Hg and 130.8/81.8 mm Hg for ABPM and OBPM, respectively. Moreover, the systolic and diastolic values during Visit 1 and Visit 3 displayed a good correlation between OBPM and ABPM (Fig. 3). This observation indicates that ABPM is effective in monitoring the patients who are either newly diagnosed with hypertension or with untreated hypertension. The mean BP readings of OBPM and ABPM are represented in Fig. 4.

Group B: study end of third month visit 4

Mean BP: OBPMvs. ABPM (overall 24-hour): The correlation between ABPM and OBPM demonstrated minimal variation in the BP readings in Group B patients

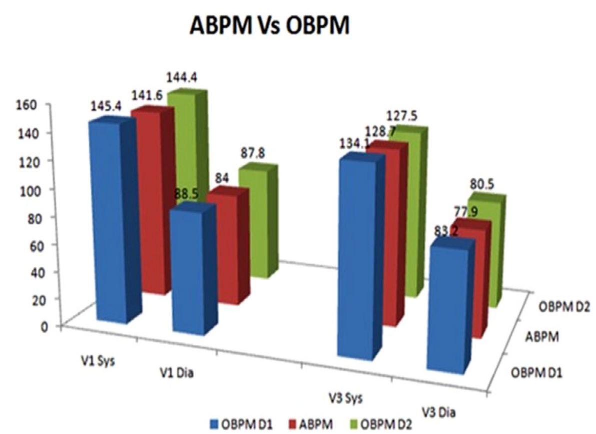

FIGURE 3. Group B - overall OBPM and ABPM mean blood pressure measurements at the end of Visit 3. Abbreviations: ABPM, ambulatory blood pressure monitoring; OBPM, office blood pressure measurement.

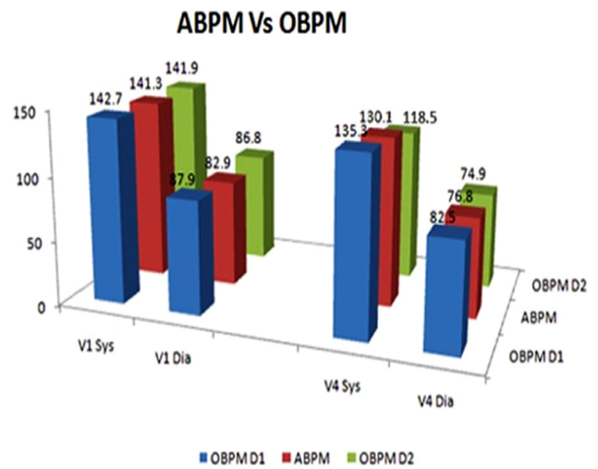

FIGURE 4. Group B - overall OBPM and ABPM mean blood pressure measurements at the end of Visit 4. Abbreviations: ABPM, ambulatory blood pressure monitoring; OBPM, office blood pressure measurement.

during Visit 4. The average ABPM during Visit 1 was 141.3/82.9 mmHg, and the average OBPM 139/85.2 mmHg; the values during Visit 4 were 130.1/76.8 mmHg and 130.2/80.8 mmHg for ABPM and OBPM, respectively. Also, the systolic and diastolic values during Visit 1 and Visit 4 for both OBPM and ABPM showed minimal variations, thereby suggesting that ABPM is effective in monitoring the patients who are either newly diagnosed with hypertension or with untreated hypertension. The mean BP measurements of OBPM and ABPM are represented in Fig. 5.

Overall hyperbaric impact

The overall hyperbaric impact is defined as the area encircled by polygonal line of ambulatory BP and two boundaries during awakening and during sleep. The hyperbaric impact which indicates cardiovascular stress imposed by overall 24-hour BP despite variations in the BP and was examined during Visit 1 and Visit 4 in Group

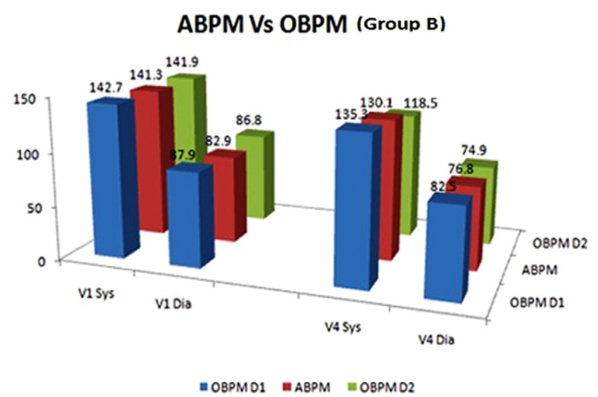

FIGURE 5. Group B - overall OBPM and ABPM mean blood pressure measurements at the end of Visit 4. Abbreviations: ABPM, ambulatory blood pressure monitoring; OBPM, office blood pressure measurement.

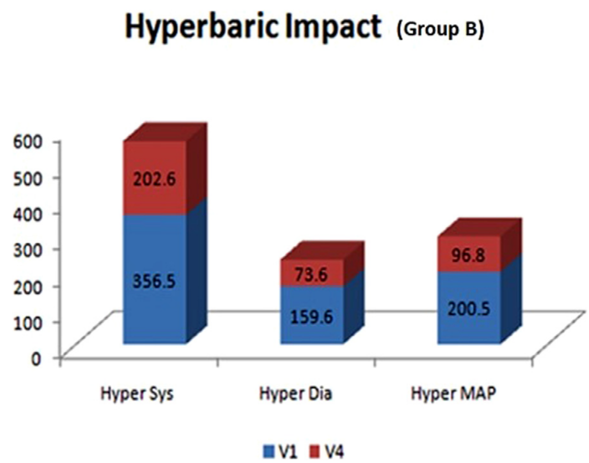

FIGURE 6. Group B - overall hyperbaric impact.

2. The hyperbaric impact was noted by measuring the hyperbaric systolic/diastolic values (Visit 4: 202/73.6; Visit 1: 356.5/159.6 mm Hg). Interestingly, the mean arterial BP measurement was higher during Visit 4 (96.8 mm Hg) as compared to that during Visit 1 (200.5 mm Hg). The variation in the hyperbaric impact is represented in Fig. 6.

DISCUSSION

Hypertension can result in significant target organ damage, such as heart disease, stroke, and chronic kidney diseases. It was one of the leading global disease burdens in 2010, and 9.4 million individuals succumb every year due to high BP.[7] About 45% of the deaths occur due to heart disease, and 51% due to stroke. This number is 24% and 57%, respectively, in India, and the prevalence of hypertension in the urban population is 40.8% and that in the rural population is 17.9% in India.[8] Importantly, a 2 mmHg decrease in the BP would prevent 151,000 deaths caused by stroke and 153,000 deaths by coronary heart disease.[9]

In India, the prevalence of hypertension is increasing. It is the leading non-communicable disease, responsible for nearly 10% mortality. The number of hypertensive individuals is estimated to grow 2-fold, i.e., from 118 million in 2000 to 213 million by 2025. Furthermore, studies conducted by the World Health Organization across 36 countries, including India, found that the treatment cost for one month was about 1.8 day's wage.[10] Thus, the expenses incurred by individuals and the government due to heart surgery, stroke care, dialysis, and other interventions related to undetected hypertension are continually rising, rendering an urgent need for the early detection and effective management of BP by regular tracking, before it becomes uncontrollable[9] and to prevent the progression to organ damage and fatal conditions, such as coronary heart disease, stroke, and chronic kidney disease.[11]

Monitoring is crucial in order to detect high BP, track the efficiency of the treatment, and to lower the risks of damage to target organs and mortality. The advantage of ABPM is that it offers multiple BP readings while the patient is performing the routine as compared to the single reading at rest in the case of OBPM.[2] Typically, the BP reading displays a reproducible temporal circadian pattern. The daytime or active/awake phase BP is elevated as compared to a physiological decrease during sleep, followed by an early morning rise (surge) during the transition from sleep to wakefulness. This diurnal pattern obtained by ABPM displayed a night-time fall in the BP termed as "dipping" and the "morning surge." Some studies have shown that the deviations from the usual patterns of these values can predict the target organ damage and cardiovascular outcomes.[12]

A prospective multicenter cross-sectional study assessed the efficacy of antihypertensive medications in chronic hypertension subjects and found that 24-hour ABPM readings distinctly displayed non-dipping, dipping, and reverse dipping patterns of BP. The current findings are in accordance with the results mentioned above, in terms of the correlation between ABPM and OBPM readings and morning surge and nocturnal dip patterns in subjects monitored by ABPM. Hence, ABPM provides a true estimate of crucial variables, such as morning surge and nocturnal dip, as compared to OBPM readings in clinical setting.[13] Moreover, 25% of the patients diagnosed with hypertension are prone to white-coat effect, i.e., the BP > 140/90 mmHg in clinical settings but normal when measured in non-clinical settings. This effect cannot be modified by standardized OBPM, resulting in under- or over-treatment in these patients. Nonetheless, the current findings of ABPM study identified the white-coat effect similar to the OBPM values, as described previously.[14,1] Therefore, some studies recommend the use of 24-hour ABPM and home BP monitoring to detect the white-coat effect.[5,15]

A prospective observational study conducted in Lucknow (India) in metabolic syndrome subjects established the efficacy of CONTEC 06 fully automated ABPM machine for tracking the average, day, and night ABPMs. These measurements are utilized for assessing the non-dipping, dipping, and reverse dipping BP patterns, which, in turn, is an effective method to track hypertension in metabolic syndrome patients.[16] Another prospective cross-sectional study in Vellore (India) detected masked hypertension, which is used for predicting left ventricular atrophy among children with chronic kidney disease. Abnormal ABPM indices, including hyperbaric index, nocturnal dipping, and overall BP load, allowed for detection of LVH and for the prediction of cardiovascular risks.[17] Furthermore, the determination of masked uncontrolled hypertension (MUCH) in hypertensive (> 140/100) and clinically normotensive patients was carried out by ABPM, which tracks the daytime and nighttime hypertension measurements, revealing a widespread prevalence of MUCH.[18]

Although the relationship between ABPM and OBPM has been reported previously, the uniqueness of this study is that it was performed in the community setting (real world), not in a specialized research center. Another feature of this trial is that it is the first of its kind to be done in South Asia, which has a large population at risk for hypertension-related morbidity and mortality and the findings serveas guidance for clinical diagnosis and treatment of hypertension. Another special dimension is that ours was an observational study and with no interventions, and thus provides important information. The findings, therefore, are readily applicable to other countries with high prevalence of hypertension.

One specific advantage of this study is that it reveals a possible advantage of ABPM over OBPM in the routine management of hypertension in the community setting by primary care doctors, not specialists. Therefore, this study confirms that ABPM as a clinical tool can be applied at the level of primary and not specialist care.

According to the guidelines of the Canadian Hypertension Education Program for ABPM, the patients are diagnosed as hypertensive if the mean awake systolic BP is ≥ 135 mmHg or the diastolic BP is ≥ 85 mmHg or if the mean 24-hour systolic BP is ≥ 130 mmHg or the 24-hour diastolic BP is ≥ 80 mmHg. Furthermore, *a* < 10% decrease in nocturnal BP increases the risk of cardiovascular events, and hence, the changes in nocturnal BP should be monitored before prescribing or withholding drug therapy based on ABPM.[19] ABPM monitoring was carried out in chronic kidney disease patients to identify abnormal hypertensive patterns by detecting dipping patterns of nocturnal BP in the study subjects. Hence, ABPM measurements enabled appropriate risk stratification by acting as an effective prognostic marker.[20] The ESH guidelines for hypertension recommended that all subjects with grade I hypertension in the office and low cardiovascular risk should be evaluated based on out-of-office BP monitoring to exclude white-coat hypertension. On the other hand, patients with normal office BP but display asymptomatic target organ damage with elevated daytime BP by ABPM or home BP monitoring, known as masked hypertension, also have been recommended for ABPM monitoring.[21]

A limitation of this study is that no therapeutic intervention was done and hence, the influence of ABPM on achieving the goal blood pressure levels is not known. In the future, it will be necessary to determine the influence of ABPM as a tool to reach the goal blood pressure levels in the community setting. Another limitation of the study is that it was undertaken in urban areas and not in the rural setting, where most people live in India. Therefore, it remains to be determined if ABPM utilization is possible in rural regions of the country. Because of the short duration of the study, it was not possible to evaluate whether careful blood pressure measurement (ABPM) influences parameters like BMI and salt intake, etc.

CONCLUSIONS

A good correlation was established between ABPM and OBPM during Visit 1 and Visit 2 in Group 1 and during Visits 1–4 in Group 2. This study demonstrates that there is no difference between ABPM and OBPM hypertension levels in patients with controlled hypertension. Whereas some differences emerge between ABPM and OBPM in patients with newly diagnosed or untreated hypertension. However, a notable variation was detected unlike previously published studies, thus, this large clinical study affirms continued usefulness of carefully obtained blood pressure measurements in the office/clinic settings. Therefore, further clinical studies should be carried out to evaluate the prevalence of masked hypertension, hypertension, and dipping patterns that are significantly associated with hypertension and other related medical co-morbidities. The study confirms the usefulness and reliability of ABPM in clinical practice.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

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