

Clinical practice of ambulatory versus home blood pressure monitoring in hypertensive patients

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Objectives This study aimed to analyze whether blood pressure (BP) measurement is concordant between ambulatory blood pressure monitoring (ABPM) and home blood pressure monitoring (HBPM), and determine whether the decision on treatment changes is similar on the basis of information provided by both methods.

Methods Treated hypertensive patients were studied with ABPM and HBPM to evaluate therapeutic efficacy and/or diagnose resistant hypertension (HTN). Modification of pharmacological treatment was decided on the basis of pre-established criteria; therefore, the number of therapeutic changes between both techniques was compared.

Results A total of 200 patients were included. The average daytime ABPM systolic blood pressure (SBP) was 136 ± 16 compared with 136 ± 15 ($P = 1$) with HBPM; the average diurnal diastolic blood pressure (DBP) was 83 ± 12 and 81 ± 9 , respectively ($P = 0.06$). The concordance between both methods was very good for SBP [$r = 0.85$; Bland–Altman 0.2 (95% confidence interval 0.9–1.4 mmHg)], and good for the DBP [$r = 0.77$; Bland–Altman 1.8 (95% confidence interval 0.8–2.8 mmHg)]. Both methods were in agreement that HTN was controlled in 68 patients and

that it was not controlled in 90 patients, that is, they were concordant in 158 patients (79%, $\kappa = 0.6$). More patients required changes with ABPM than HBPM (149 vs. 99 patients, $P < 0.0001$)

Conclusion There were no significant differences in the measurement of diurnal SBP and DBP between both methods. The concordance to determine proper control of HTN was 79%. There was a significant difference in the decision to modify the treatment in favor of the ABPM. *Blood Press Monit* 00:000–000 Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.

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Introduction

Hypertension (HTN) is a powerful risk factor responsible for significant cardiovascular morbidity and mortality worldwide [1]. Effective antihypertensive treatment prevents the occurrence of cardiovascular events irrespective of the antihypertensive agent used [2]. Traditionally, the diagnosis of HTN has been made with office blood pressure (BP) measurements, but BP assessment in an environment away from the office, using ambulatory blood pressure monitoring (ABPM) and home blood pressure monitoring (HBPM), has gained acceptance [3,4]. The development of automated oscillometric devices validated by international guidelines and consensus has led to widespread use of both methods [1,5]. ABPM and HBPM provide multiple measurements reflecting BP variations that enable a more precise diagnosis of HTN and assessment of its proper control during day and night compared with office monitoring [6–8]. Both methods enable the diagnosis of white-coat and masked HTN, and have proven to be more effective than office measurements in the prediction of cardiovascular events, target organ damage, and prognosis [9–11]. The main advantage of ABPM over HBPM is the capability to follow BP behavior during sleep [12,13].

The extent by which additional information provided by ABPM impacts on therapeutic decisions compared with the information provided by HBPM has not been clarified. The objectives of this study were as follows:

- (1) Compare systolic blood pressure (SBP) and diastolic blood pressure (DBP) averages measured by both techniques.
- (2) Evaluate concordance between ABPM and HBPM to determine whether HTN is controlled.
- (3) Determine whether the decision to make changes in the treatment of patients with HTN is similar on the basis of the information provided by both methods.
- (4) Assess whether an algorithm that combines both methods in complementary manner is beneficial in treated hypertensive patients.

Methods

Patients of 18 years or older with the diagnosis of HTN who were treated at our institution and required ABPM to evaluate therapeutic efficacy and/or diagnose resistant HTN were invited to participate in the study. ABPM was performed with Meditech-04 devices and HBPM with

Table 1 ABPM and HBPM hypertension definition

ABPM 24 h	130	80
ABPM daytime	135	85
ABPM night-time	120	70
HBPM	135	85

ABPM, ambulatory blood pressure monitoring; HBPM, home blood pressure monitoring.

semiautomatic BP monitors OMRON (7101 HEM – HEM 742; Kyoto, Japan) or MICROLIFE (BP 3AC1-1; Widnau, Switzerland), validated by international organizations [1,14,15]. On the same day, ABPM was started; automatic BP monitors were provided to the patients for HBPM. ABPM lasted 24 h and readings were obtained every 15 min during daytime (7 a.m. to 23 p.m.) and every 30 min during night-time (23 p.m. to 7 a.m.), with a minimum of 60 samples for the study to be considered satisfactory. The ABPM device was placed on the non-dominant arm to improve the tolerance and quality of the readings. Patients were instructed to carry on with their usual activities and the monitor was removed the next day. The average 24 h, daytime, night-time BP, and night patterns (dipper, nondipper, and over-dipper) were recorded.

HBPM was carried out during 4 days, starting the same day as ABPM, with two readings in the morning (between 7 a.m. and 10 a.m.) and two in the evening (between 8 p.m. and 10 p.m.) each day, with a 5 min interval between readings [16]. These measurements were performed before the administration of anti-hypertensive medication. All values were registered and compared with those recorded in the device memory. This protocol was in agreement with the European and American Hypertension guidelines that recommend HBPM for at least 3 days, preferably 7 days, with a minimum of two samples in the morning and two at night [1,16,17]. During the first day, HBPM was performed in the dominant arm and when ABPM was concluded, HBPM readings were switched to the nondominant arm. The average BP was calculated for both monitoring methods and cut-off limits to define uncontrolled HTN were established according to recommendations of the European Society of Hypertension (Table 1) [1,18].

Criteria that had to be fulfilled to modify treatment were also pre-established. For ABPM change of medication, criteria were that average BP during 24 h, daytime, or night-time period exceeded the normal limits or demonstration of abnormal sleeping patterns such as nondipper (nocturnal/diurnal BP relationship >0.9) or over-dipper (nocturnal/diurnal BP relationship <0.8) [1, 19,20]. For HBPM information, change of medication criterion was that average SBP or DBP exceeded normal values established by guidelines (Table 1) [1,18]. Finally, to assess the advantages of using both outpatient-monitoring methods in a complementary manner, we

applied an algorithm described by Pickering *et al.* [21]. This protocol was originally conceived for patients with no history of HTN; thus, this is the first report in treated hypertensive patients. The algorithm started evaluation of all hypertensive patients using HBPM. Those with BP less than 125/75 mmHg would continue with the same treatment; those with BP more than 135/85 mmHg should have their medication adjusted; and patients with BP between 125/75 and 135/85 mmHg should be evaluated with ABPM to confirm whether HTN is properly controlled.

Statistical analysis

For continuous variables, data were expressed as mean (\pm) SD or median (\pm) range; differences compared using the Student *t*-test or the Mann–Whitney test when appropriate. For discrete variables, data were expressed as percentages and were compared using the χ^2 -test or the Fisher test when appropriate.

To evaluate concordance index of SBP and DBP between both methods, an interclass correlation coefficient was calculated according to the Bland–Altman method [22].

The concordance between both methods to determine the adequate BP control was determined by the calculation of the κ index using the scale proposed by Altman [23]: value of $\kappa < 0.20$: poor, 0.21–0.40: weak, 0.41–0.60: moderate, 0.61–0.80: good and 0.81–1.00: very good.

Finally, the absolute frequencies (%) for change of treatment were calculated for both BP monitoring modalities and compared using McNemar's method.

Results

Patient characteristics

Between September 2012 and July 2013, 200 treated hypertensive patients were included. The baseline characteristics are summarized in Table 2. There were 116 men and 84 women, with an average age of 56 ± 12 years. Overall, 38% were dyslipemic, 19% were diabetic, 15% were smokers, 8% had known coronary artery disease, and 9% had suffered previous cardiovascular events. In all, 40% of patients were receiving anti-hypertensive treatment with one drug, 38% with two drugs, and 22% with three or more drugs.

Similarity between both methods in the measurement of systolic and diastolic blood pressures

ABPM diurnal SBP average was 136 ± 16 and 136 ± 15 mmHg ($P=1$) by HBPM; DBP was 83 ± 12 and 81 ± 9 mmHg, respectively ($P=0.06$) (Table 3, Figs 1 and 2). Concordance was very good for SBP [$r=0.85$; Bland–Altman 0.2 (95% confidence interval 0.9–1.4 mmHg)] and good for DBP [$r=0.77$; Bland–Altman 1.8 (95% confidence interval 0.8–2.8 mmHg)] as shown in Figs 3 and 4.

Table 2 Baseline characteristics

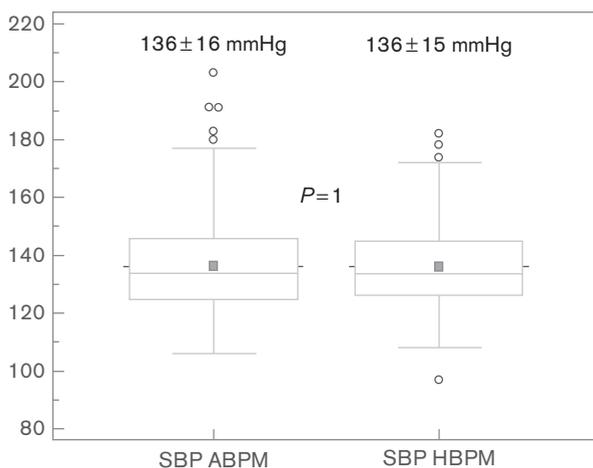
N=200 [n (%)]	
Male	116 (58)
Age	56 ± 12
Dyslipidemia	76 (38)
Diabetes mellitus	37 (19)
Smoking	30 (15)
Coronary artery disease	15 (8)
History of CV event (AMI or stroke)	18 (9)
Antihypertensive drugs	
β-Blocker	78 (39)
ACE inhibitors	41 (20.5)
ARB	119 (59.5)
Calcium blocker	60 (30)
Diuretic	68 (34)
Another	12 (6)
Antihypertensive drug number	
One drug	79 (40)
Two drugs	77 (38)
Three or more drugs	44 (22)

ACE, angiotensin-converting enzyme; AMI, acute myocardial infarction; ARB, angiotensin receptor blocker; CV, cardiovascular.

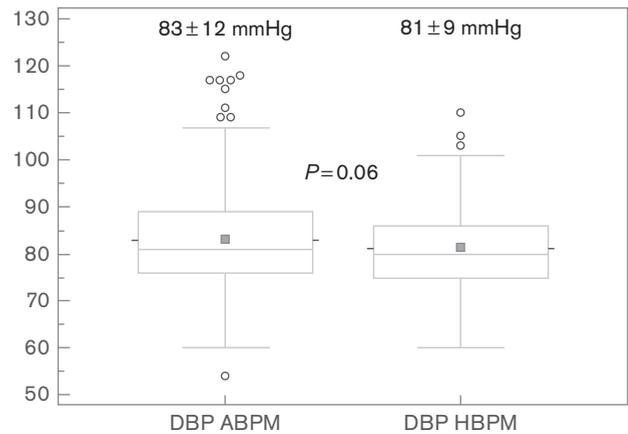
Table 3 Blood pressure measurements performed with ABPM and HBPM

Average BP (mmHg)	ABPM	HBPM
General		
Systolic	131 ± 15	–
Diastolic	79 ± 11	–
Daytime		
Systolic	136 ± 16	136 ± 15
Diastolic	83 ± 12	81 ± 9
Night-time		
Systolic	123 ± 16	–
Diastolic	71 ± 12	–
ABPM sleep patterns [n (%)]		
Dipper	101 (51)	–
Over-dipper	5 (3)	–
Nondipper	94 (46)	–

ABPM, ambulatory blood pressure monitoring; BP, blood pressure; HBPM, home blood pressure monitoring.

Fig. 1

Average daytime systolic blood pressures (SBPs) with ABPM and HBPM. ABPM, ambulatory blood pressure monitoring; HBPM, home blood pressure monitoring.

Fig. 2

Average daytime diastolic blood pressures (DBPs) with ABPM and HBPM. ABPM, ambulatory blood pressure monitoring; HBPM, home blood pressure monitoring.

Agreement between ABPM and HBPM to determine HTN control

ABPM showed adequate BP control in 77 patients (39%) and lack of control in 123 patients (61%). With HBPM, 101 patients (51%) were controlled and 99 patients (49%) were not. Both methods agreed in identifying 68 patients (34%) with well-controlled HTN and 90 (45%) without adequate control. Both methods concurred in predicting BP control in 79% of the cases (158 patients, index κ 0.6). In 42 patients (21%), there was no coincidence; 33 of them were not well controlled by ABPM and were controlled by HBPM. Nine were properly controlled by ABPM and not by HBPM (Table 4). Nonconcordance was because of nocturnal HTN or abnormal BP patterns during sleep time in 71% of cases.

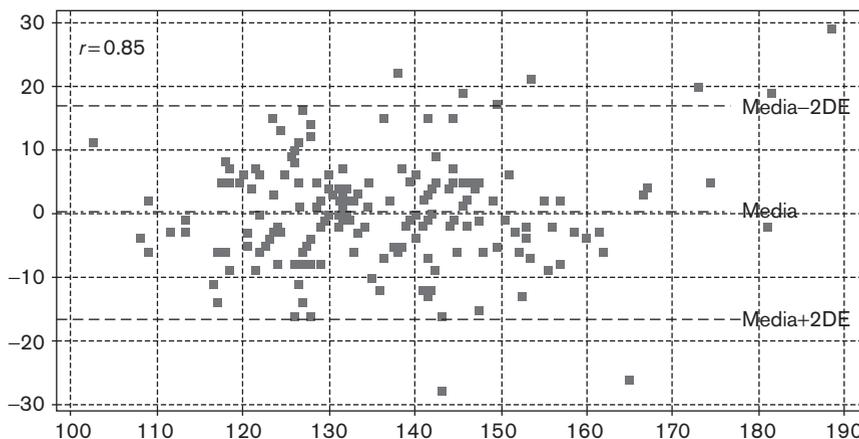
Decision to make changes in antihypertensive treatment

Following pre-established rules to introduce changes in antihypertensive treatment, 149 patients (75%) should have undergone treatment modification after information provided by ABPM compared with 99 patients (49%) after HBPM results ($P < 0.0001$). Of the 149 patients who needed treatment changes after ABPM, 123 (83%) were because HTN was not controlled. The remaining 26 patients (17%) showed abnormal night-time BP behavior: a nondipper pattern in 24 and an over-dipper pattern in two patients. If the nocturnal pattern of BP had not been considered as a cause for treatment modification, the difference between both monitoring methods would have been lower but still significant (61% for ABPM vs. 49% for HBPM, $P = 0.02$) as shown in Fig. 5.

Implementation of Pickering's algorithm

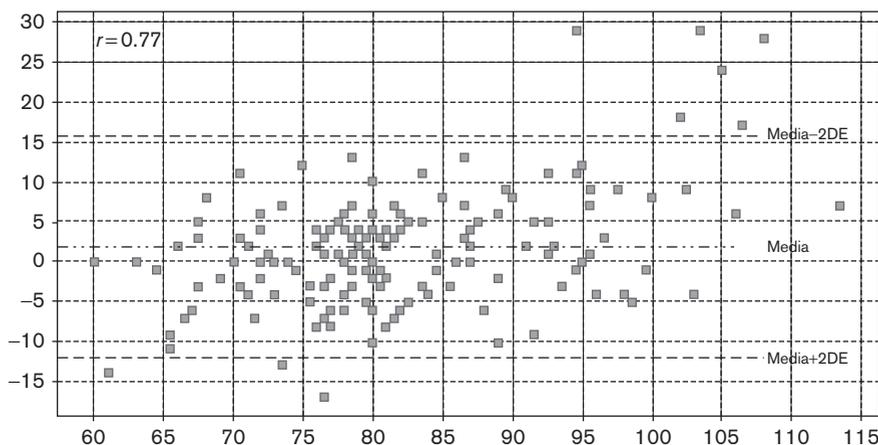
Algorithm application yielded that 30 patients (15%) would not have required medication change as HBPM average BP was less than 125/70 mmHg. Of this group,

Fig. 3



ABPM and HBPM systolic blood pressure concordance analysis. ABPM, ambulatory blood pressure monitoring; HBPM, home blood pressure monitoring.

Fig. 4



ABPM and HBPM diastolic blood pressure concordance analysis. ABPM, ambulatory blood pressure monitoring; HBPM, home blood pressure monitoring.

Table 4 Blood pressure control in hypertensive patients on the basis of ABPM and HBPM

	ABPM [n (%)]	HBPM [n (%)]
Controlled HTN	77 (39)	101 (51)
Noncontrolled HTN	123 (61)	99 (49)
Controlled by ABPM and HBPM	68 (34)	
Not controlled by ABPM and HBPM	90 (45)	
Concordance between ABPM and HBPM	158 (79)	
Nonconcordance between ABPM and HBPM	42 (21)	
Not controlled by ABPM and controlled by HBPM	33 (16.5)	
Not controlled by HBPM and controlled by ABPM	9 (4.5)	

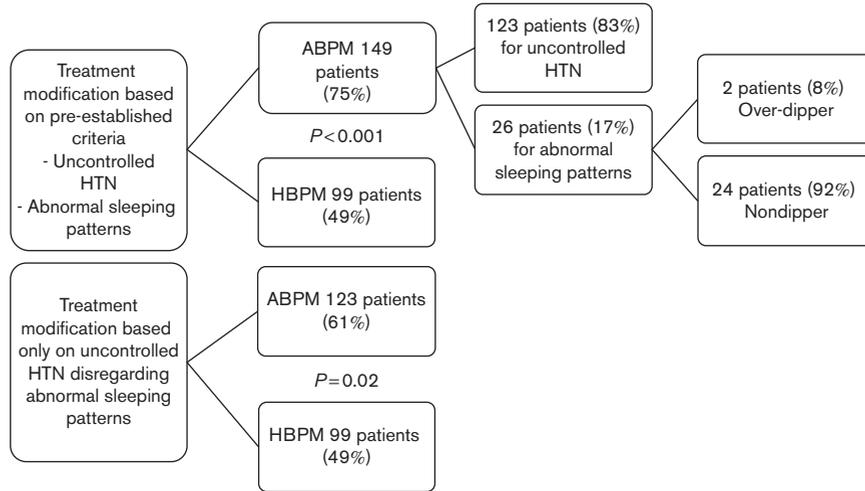
ABPM, ambulatory blood pressure monitoring; HBPM, home blood pressure monitoring; HTN, hypertension.

26 (87%) were confirmed by ABPM. Ninety-nine patients (50%) would have required medication modification with HBPM as BP was 135/85 mmHg, of which ABPM agreed in 90 patients (91%). Finally, 71 patients (35%) would have required ABPM because BP was between 125/75 and 135/85 mmHg by HBPM, of whom 29 patients (40%) had well-controlled BP and 42 (60%) did not (Fig. 6).

Discussion

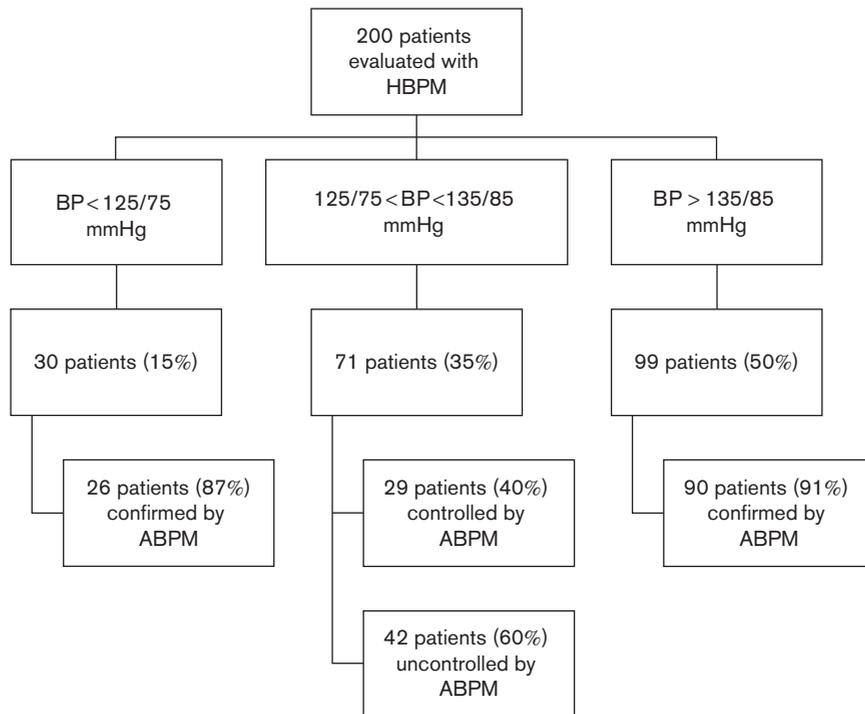
This study shows that both ambulatory monitoring methods are concordant in SBP and DBP measurements. Both methods also agree if BP is properly controlled in

Fig. 5



Changes in antihypertensive treatment. ABPM, ambulatory blood pressure monitoring; HBPM, home blood pressure monitoring; HTN, hypertension.

Fig. 6



Algorithm for complementary utilization of ABPM and HBPM. ABPM, ambulatory blood pressure monitoring; BP, blood pressure; HBPM, home blood pressure monitoring.

hypertensive-treated patients. Changes in HTN treatment on the basis of information provided by both methods were significantly higher with ABPM because of sleep time BP behavior monitoring.

The 2013 Hypertension European Guidelines recommend HBPM as a first-line strategy in HTN management

because of simplicity, wide availability, low cost, and patient convenience [1]. Day-to-day BP variability can be assessed using this method for extended periods, enabling long-term HTN evaluation [7,23]. ABPM can also provide detailed information on the daily activity influence on BP, but its major advantage over HBPM is that it provides sleep hour measurements allowing

nocturnal HTN diagnosis, and relative changes to average day BP, such as dipping, nondipping, and over-dipping patterns of nocturnal BP. The main limitations of ABPM are the high cost for its widespread use and the moderate discomfort that some patients experience [24]. Considering the advantages and disadvantages of both methods, they should be considered complementary rather than competitive or alternative [1].

In this study, we aimed to verify whether their results are concordant. The average SBP and DBP were highly concordant between both methods ($r=0.85$ and 0.77), results somewhat superior to those reported by other researchers [25]. Both methods were equally effective in determining whether or not HTN was controlled. Nonconcordance was because of nocturnal HTN or abnormal BP patterns during sleep time in two-thirds of patients. This additional information provided by ABPM also explains why modification of treatment was significantly more frequent after ABPM than following HBPM.

Pickering *et al.* [21] proposed an algorithm that combines both ambulatory methods to diagnose HTN in previously untreated patients. Implementation of this algorithm in treated HTN patients is a novel approach that could improve diagnostic and therapeutic ability with lower cost and greater convenience. If this algorithm were applied to the patients studied, ABPM would only be required in 77 patients (35%) (with BP between 125/75 mmHg and 135/85 mmHg with HBPM) rather than in 200 patients. Although some patients with BP above 135/85 mmHg after HBPM could eventually require ABPM to confirm adequate degree of HTN control, it is clear that applying this algorithm can potentially reduce costs by taking advantage of both methods in a complementary manner. This algorithm could be applied to the majority of hypertensive patients; however, there are specific situations in which ABPM should be the first and the only outpatient method: BP variability evaluation over a short time period and mostly, in suspected cases of nocturnal HTN or in patients with sleep apnea, in which HBPM does not provide sufficient information.

Among the limitations of this study, it should be noted that with HBPM, BP measurements were not recorded during 7 days as recommended. However, the recent European guideline recommends that 3-day evaluation with a total of 12 samples is sufficient [1]. In the present study, readings were obtained during 4 days, with a total of 16 BP readings per patient; therefore, the information obtained was likely adequate. Treatment modification simply by finding an abnormal sleep BP behavior such as nondipper or over-dipper patterns in treated patients with normal BP is questionable. This issue is valid as both BP patterns have shown limited reproducibility, and modifying treatment by these daytime and night-time

patterns has not resulted in cardiovascular event reduction [19]. However, in clinical practice, it is common to make therapeutic changes when these patterns are found in an ABPM report. If the presence of these patterns would not have promoted therapeutic changes in this study, treatment changes between ABPM and HBPM would have decreased from 75 versus 49% ($P=0.001$) to 61 versus 49%, ($P=0.02$), respectively, but would remain significant. Finally, this study did not aim to validate Pickering's algorithm, but rather to assess how it would have impacted patient care had it been applied. We believe that a formal prospective trial would be required to properly validate this algorithm.

Conclusion

In hypertensive patients, HBPM and ABPM show similar results on average SBP and DBP measurement, resulting in concordance to determine whether BP is appropriately controlled. Changes in BP medication were greater after ABPM because of its capability to detect nocturnal HTN and abnormal BP behavior during sleeping hours. Application of an algorithm to use both types of BP monitoring in a complementary manner is reasonable and could potentially reduce costs.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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