

# Arm Position During Ambulatory Blood Pressure Monitoring: A Review of the Evidence and Clinical Guidelines

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Ambulatory blood pressure monitoring (ABPM) offers advantages over clinic blood pressure measurement. Supporting the arm at the level of the right atrium has long been standard in clinic blood pressure measurement. In contrast, there is no consensus regarding arm position in the guidelines addressing ABPM. Research studies have used a variety of arm positions during ABPM. Discussed in this review are the merits of ABPM and a review of the several arm positions recommended in ABPM guidelines, suggested

by cuff manufacturers, and used in research studies. To address this lack of standardization, a rationale for a clinically reasonable arm position during ABPM is offered. Specifically, the authors recommend advising the patient to keep the arm still and relaxed straight down at the side of the body when the cuff is going to inflate, when safe to do so. *J Clin Hypertens (Greenwich)*. 2014;16:225–230. ©2014 Wiley Periodicals, Inc.

Hypertension (HTN) is common and associated with an increased risk of coronary heart disease events and stroke. Whereas treatment of sustained HTN is associated with increased life expectancy,<sup>1</sup> treatment of nonsustained (“white-coat”) HTN is likely of little benefit.<sup>2</sup> Ambulatory blood pressure (BP) monitoring (ABPM) has been recommended as a tool for identifying white-coat HTN, as well as for identifying masked HTN, nocturnal HTN, and well-controlled HTN.<sup>3,4</sup> ABPM measurements are more strongly associated with cardiovascular morbidity and mortality compared with office-based measurements.<sup>5,6</sup> However, unnecessary variation in technique threatens to introduce errors into ABPM measurements. We discuss why arm position in ABPM should be considered a well-established source of unnecessary variation. In addition, we review the variation that exists in guidelines regarding arm position during ABPM. We discuss the various arm positions used in ABPM research studies, and we recommend a standard arm position.

## BP MEASUREMENTS DIFFER ACCORDING TO ARM POSITION

In 1897, Hill and Barnard stated that arm position must be standardized during cuff-based BP measurement since the measurement changes as the arm is raised or lowered. The expected change in BP attributable to gravity upon raising or lowering of the arm can be calculated<sup>7</sup> as:

$\Delta bp = d_v \cdot \frac{sg_b}{sg_m}$ , where  $bp$  is the cuff-measured BP in the arm (mm Hg),  $d_v$  is the vertical distance from the right atrium (in mm),  $sg_b$  is the specific gravity of blood

(1.05 at 37°C),<sup>8</sup> and  $sg_m$  is the specific gravity of Hg (~13.6).

This formula accurately predicts the observed change in BP with passive arm elevation or lowering. The BP changes by ~0.77 mm Hg for every centimeter (~2 mm Hg per inch) of distance between the cuff and the phlebostatic axis, commonly estimated at the fourth intercostal space. When the arm is perpendicular to the torso, systolic BP has been shown to be 8.8 mm Hg lower and diastolic BP to be 10.1 mm Hg lower than when the arm is parallel to the torso.<sup>9</sup> This is a clinically significant difference in measurement of BP similar in magnitude to the typical effects of an antihypertensive medication. The recommendation that the cuff be at the level of the heart (ie, right atrial) is considered indispensable in seated clinic BP measurement.<sup>4</sup> Despite the well-known relationship between arm position and BP measurements and a strong consensus regarding arm position during office BP measurement, ABPM guidelines recommend a variety of arm positions, and ABPM-based research studies have used a variety of arm positions, as we discuss below.

## RATIONALE FOR A STANDARD ARM POSITION IN ABPM

### An Effect of Arm Position on ABPM Measurements Has Been Demonstrated

The impact of arm position on BP measured by ABPM is not a merely theoretical concern. At least two studies clearly demonstrate that arm position affects BP measurements in ABPM.<sup>10,11</sup> Mourad and colleagues randomized hypertensive patients to different arm positions during ABPM monitoring. Waking ABPM measurements with the arm “in the usual position for ABPM” were an average of 13/8 mm Hg higher compared with measurements taken with the arm in the horizontal position (with or without arm support at the patient’s discretion). In addition, they found that this arm position–related artifact increased as BP increased.<sup>11</sup>

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**Manuscript received:** September 8, 2013; **revised:** November 26, 2013; **accepted:** November 29, 2013  
**DOI:** 10.1111/jch.12255

**TABLE. Suggested Arm Positions (If Any) According to Clinical Hypertension Guidelines for ABPM**

Author, Year (Reference)	Recommended Arm Position	Comments
Fourth International Consensus Conference on 24-Hour Ambulatory Blood Pressure Monitoring, 1995 <sup>12</sup>	"Measurement error caused by the position of the upper arm may be prevented during the day by asking subjects to ensure that the arm is always parallel to the trunk when the cuff is inflated. However, this is not feasible at night."	This statement directly addressed the issue of arm position. However, the advice has not been consistently integrated into guidelines. The failure of subsequent guidelines to incorporate this recommendation may reflect concerns about hydrostatic pressure. The position differs from that promulgated for seated measurements by most authorities, thus producing a measured blood pressure (BP) differentially perturbed by hydrostatic pressure. Nonetheless, this remains the most practical, and likely the most reproducible, arm position.
British Hypertension Society 2000 <sup>27</sup>	<p>"Instruct patients</p> <ul style="list-style-type: none"> <li>• to keep their arm steady during measurement</li> <li>• to keep their arm at heart level during measurement"</li> </ul>	Patients and physicians may be unsure whether this recommendation is better achieved with a relaxed or fully extended arm (neither of which is consistent with the usual interpretation of "at heart level"). The location of "heart level" is not specified.
Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7), 2003 <sup>28</sup>	No recommendation regarding arm position in ambulatory BP monitoring (ABPM).	This lack of advice may lead to the adoption of widely varying arm positions in clinical practice.
European Society of Hypertension, 2003 <sup>29</sup>	"It is essential, therefore, for the arm to be supported during blood pressure measurement, especially when the individual is in the standing position, and this is best achieved in practice by having the observer hold the person's arm at the elbow, although in research the use of an arm support on a stand has much to commend it."	The authors make several comments on arm position in BP measurement. The comments center on the importance of keeping the forearm at heart level and the error introduced by allowing dependency of the arm, especially during standing. The authors acknowledge the importance of patient instructions in ABPM but do not specify the instructions. No comment on arm position specifically during ABPM is made, but the comments on arm position during BP measurement in general state that the arm should not be in the dependent position. We agree that the BP measured with the arm in the dependent position will be higher compared with BP measured when the arm is at the level of the heart. Yet, we believe that this shortcoming is outweighed by the convenience and patient-oriented nature of the instruction we have proposed, since even healthcare providers may disagree about the meaning of "heart level."
	"Posture affects blood pressure, with a general tendency for it to decrease from the lying to sitting or standing position. However, in most people posture is unlikely to lead to significant error in blood pressure measurement, provided the arm is supported at heart level."	
	"The forearm must also be at the level of the heart as denoted by the mid-sternal level. Dependency of the arm below heart level leads to an overestimation of systolic and diastolic pressures and raising the arm above heart level leads to underestimation. The magnitude of this error can be as great as 10 mm Hg for systolic and diastolic readings. This source of error becomes especially important for the sitting and standing positions, when the arm is likely to be dependent by the individual's side."	
	"The key to successful ABPM is educating the patient on the process of monitoring and the instructions should be explained and printed on a diary card." The instructions described are:	
	<ul style="list-style-type: none"> <li>• "Give patient written instructions and a diary card</li> </ul>	

**TABLE. Suggested Arm Positions (If Any) According to Clinical Hypertension Guidelines for ABPM (Continued)**

Author, Year (Reference)	Recommended Arm Position	Comments
British Hypertension Society guidelines, 2004 <sup>30</sup>	<ul style="list-style-type: none"> <li>Instruct patient how to remove and inactivate monitor after 24 h”</li> </ul> <p>Arm position in clinic BP measurement is described. However, no advice is offered regarding arm position in ambulatory BP monitoring.</p>	This lack of advice may lead to the adoption of widely varying arm positions in clinical practice.
American Heart Association Scientific Statement, 2005 <sup>4</sup>	“It is important to <i>instruct the patient to hold the arm still by the side while the device is taking a reading.</i> ”	No comment is made regarding the position of the arm.
Brazilian Society of Cardiology guidelines, 2005 <sup>31</sup>	“Keep the arm still and hanging relaxed along the body.”	These guidelines present detailed patient instructions.
European Societies of Hypertension and Cardiology guidelines, 2007 <sup>32</sup>	“Instruct the patients to engage in normal activities but to refrain from strenuous exercise, and to keep the arm extended and still at the time of cuff inflations.”	The “extended arm” position is at odds with earlier guidelines. Also, extending the arm involves isometric exercise or the use of an arm support, which cannot be assumed to be available during ambulatory monitoring. Moreover, the height of the arm relative to the heart in this extended position is vague.
Italian Society of Hypertension guidelines, 2005 <sup>33</sup>	“The patient should be instructed about the procedures to follow during each automatic BP measurement and in particular he or she should be asked to keep the arm still and to remain motionless at the time of automatic cuff inflations.”	The position of the arm is not described.
Japanese Circulation Society ABPM Guidelines—Digest Version, 2012 <sup>34</sup>	“Instructions for subjects <i>Do not move the cuffed upper arm during measurement.</i> ”	The position of the arm is not described.
National Institute for Clinical Excellence (NICE) guidelines, 2011 <sup>35</sup>	“When measuring blood pressure in the clinic or in the home, standardise the environment and provide a relaxed, temperate setting, with the person quiet and seated, and their arm outstretched and supported.” “When using ABPM, patients need some understanding of how the device works and instruction about manual deflation, missed readings, arm position, and machine location: fitting takes 15–30 min.”	The guideline does not state whether “arm outstretched and supported” applies to ABPM, but the context suggests it does not.
British Hypertension Society Standard Operating Procedure for ABPM, developed in response to 2011 NICE guidelines <sup>36</sup>	“Tell them to stand or sit still with their arm supported during the measurement. (They can support their arm with their other arm if they are standing or rest it on a desk, table, cushion or pillow when sitting)... The cuff must be at heart level whenever a measurement is done.”	These guidelines clearly state the importance of arm position but do not provide guidance on “heart level.”
Australian Consensus Statement, 2012 <sup>37</sup>	“When the cuff starts inflating, keep the cuff at heart level, temporarily stop moving or talking for about 1 min, keep the arm immobilized and relaxed and try to relax and breathe normally.”	Patients and physicians may be unsure whether this recommendation is better achieved with a relaxed, partially extended or fully extended arm. Again, “heart level” is not well-described.
Canadian Hypertension Education Program guidelines, 2013 <sup>38</sup>	The position of the arm is not described.	This lack of advice may lead to widely varying arm positions adopted in clinical practice.
International Society for Chronobiology, American Association of Medical Chronobiology and Chronotherapeutics, Spanish Society of Applied	“Patients must be specifically instructed to: keep the cuff at heart level, cease moving or talking, keep the	Patients and physicians may be unsure whether this recommendation is better achieved with a relaxed, partially extended, or fully extended arm. Again, “heart level” is not well-described.

**TABLE. Suggested Arm Positions (If Any) According to Clinical Hypertension Guidelines for ABPM (Continued)**

Author, Year (Reference)	Recommended Arm Position	Comments
Chronobiology, Chronotherapy, and Vascular Risk, Spanish Society of Atherosclerosis, and Romanian Society of Internal Medicine guidelines, 2013 <sup>39</sup> European Society of Hypertension Position Paper on Ambulatory Blood Pressure Monitoring, 2013 <sup>40</sup>	arm still and relaxed, and breathe normally when the cuff starts to inflate"  "It is important to emphasize to the patient to follow his/her usual daily activities but, as much as possible, to remain still with the arm relaxed and not extended or contracted at heart level during each BP measurement."	The patient is instructed to place the arm at "heart level," but "heart level" is not defined, leaving the arm position open to interpretation by healthcare providers and patients.

Kammila and colleagues noticed a large number of patients with excessive nocturnal dipping after instructing patients to use a pillow to muffle the sounds of the ambulatory monitor. They therefore evaluated whether asking patients not to elevate their arm on a pillow during ABPM would yield higher BP measurements. After implementing this instruction, the percentage of patients diagnosed with excessive nocturnal dipping decreased from 17.4% to 8.8% for systolic BP and 37.0% to 24.4% for diastolic BP. The percentage of patients diagnosed with inadequate nocturnal dipping increased from 33.7% to 45.6% for systolic BP and from 13.0% to 31.6% for diastolic BP.<sup>10</sup> As illustrated in these studies, ABPM measurements vary significantly with arm position during the day and at night. Therefore, whether BP measured by ABPM during clinical practice is truly comparable to those reported by ABPM research studies depends on the position of the arm in both scenarios. Misclassification of patients' BP and unjustified adjustments of BP medications would be an expected consequence if the arm position used in routine clinical practice is unlike that employed in ABPM research protocols, the results of which inform management guidelines.

**Prior and Current Recommendations for Arm Position in ABPM Lack Agreement**

In 1995, Staessen and colleagues published a consensus view in which they recommended an arm position for ABPM ("parallel to the trunk").<sup>12</sup> Nonetheless, several more recent clinical guidelines make no specific recommendation regarding arm position. Other guidelines recommend arm positions varying from "still and hanging relaxed along the body" to "at heart level" to "supported" at heart level to "extended." The Table lists the arm positions (if any) suggested in a variety of clinical hypertension guidelines addressing ABPM. It is clear that at present there is no uniformity to these recommendations.

**A Variety of Arm Position Have Been Used in ABPM-Based Research**

High-impact studies of ABPM have implemented different patient instructions regarding arm position. Of 25 ABPM studies reviewed by the Agency for Healthcare Research & Quality, only 11 (44%) stated that instructions regarding ABPM were given to patients. In the Pressioni Arteriose Monitorate E Loro Associazioni (PAMELA) study, participants undergoing ABPM were instructed to "hold the arm immobile at the time of the measurements."<sup>13</sup> The position of the arm was not prescribed by the investigators. Other publications describe the arm position in adequate detail. Wendelin-Saarenhovi and colleagues instructed their elderly study participants to "to avoid strenuous physical exercise and to keep the arm in a relaxed position by the side of the body for the BP recording."<sup>14</sup> Another highly productive ABPM research group has reported varying patient instructions, including "arm by the patient's

side” (2007)<sup>15</sup> and “arm extended” (2007, 2009 and 2011).<sup>16–18</sup> The manuals for the ABPM devices used in these and other research studies are not in accord with regard to arm position. Surprisingly, even a study designed to assess factors affecting reproducibility of ABPM did not report instructing the patients regarding the height of the arm during measurements.<sup>19</sup>

The International Database on Ambulatory Blood Pressure Monitoring in Relation to Cardiovascular Outcomes (IDACO) is a database of results from 10 large ABPM studies conducted across several continents. Whereas IDACO has been highly informative about ABPM, some publications from IDACO’s constituent studies did not describe arm position during ABPM. We cannot comment, therefore, on whether the arm position was standardized during these seminal studies.<sup>13,20–26</sup>

## A PROPOSED STANDARD ARM POSITION

In view of the increasing use of ABPM, we believe it is critical to standardize the arm position during ABPM, as much as is possible, to mitigate this important source of variation. Any recommendation for a standard arm position is open to criticism, since each arm position has potential drawbacks. Extension of the arm perfectly perpendicular to the body requires isometric exercise (which may spuriously contribute to BP elevations) and places the cuff slightly higher than the right atrium. Placing the arm “at heart level” may or may not involve isometric exercise since this instruction is open to a variety of reasonable interpretations. The most accurate BP measurements while standing and sitting during ABPM measurement might result from instructing patients to support the arm on a table while seated or a shelf while standing so that the middle portion of the cuff is at the fourth intercostal space. It would require the patient to always be near a chair and table of appropriate height for measurements or seek a support to rest their arm on while standing. In addition, this instruction requires patients to understand nonobvious aspects of surface anatomy. Yet, some current guidelines incorporate impractical aspects of this idealized method.

We suggest that healthcare providers performing ABPM instruct patients: “If you are in a situation in which it is safe to do so, keep your arm still and relaxed straight down at the side of your body when the cuff is going to inflate (whether seated, standing, or lying down.)” Although the mid-cuff will likely be slightly below the right atrium (ie, measurements may be higher compared with those taken with the arm supported at heart level), the instruction is simple, requires little or no interpretation, requires no support for the arm, does not involve isometric exercise, and accords with instructions that have been used in some ABPM research studies. We recognize that this arm position may lead to ABPM averages that would be several mm Hg higher compared with measurements done with the arm at a higher “heart level” position. In addition, many studies have not disclosed the arm position used during ABPM, so there

may be more uniformity than can be appreciated from a review of published manuscripts, minimizing the impact of a standardization effort. Nonetheless, we believe the well-understood benefits of standardization of research and clinical BP measurements outweigh these limitations. A reasonable recommendation would be to use the ABPM cuff to measure the seated BP using standard clinical technique and standing BP with the arm relaxed by the patient’s side. This approach would suggest a correction factor, at least for daytime measurements. Finally, we believe that it is also technologically feasible for manufacturing companies to provide a sensor of arm position relative to the heart and to provide both raw BP readings as well as those corrected for the estimated extra hydrostatic pressures using this uniform protocol.

## CONCLUSIONS

Studies establishing the usefulness of ABPM have used a variety of patient instructions regarding arm position. ABPM measurements remain a powerful predictor of cardiovascular events despite the lack of arm position standardization. To the extent that unnecessary arm position variation exists in ABPM, noise is being introduced into the measurements. We speculate that should this noise be removed, ABPM levels might be an even stronger predictor of BP-related cardiovascular events. Unfortunately, present-day guidelines vary in their recommendations regarding arm position in ABPM. The variation in arm positions used in studies presents a barrier to direct translation of ABPM-based BP goals to clinical practice. A renewed effort to standardize arm position during ABPM protocols for research and clinical practice is needed. This standardization effort should promote the instruction: “If you are in a situation in which it is safe to do so, keep your arm still and relaxed straight down at the side of your body when the cuff is going to inflate (whether seated, standing, or lying down.)”

*Disclosures:* The authors report no specific funding in relation to this research and no conflicts of interest to disclose.

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