

## Hypertension Curriculum Review

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## Measurement of Blood Pressure In and Out of the Office

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Although hypertension can only be identified by measuring blood pressure (BP), the conventionally used methods for its detection are notoriously unreliable. There are three main reasons for this: inaccuracies in the methods, some of which are avoidable; the inherent variability of BP; and the tendency for BP to increase in the presence of a physician (white coat effect). For clinical practice, the gold standard is measurements made with the auscultatory technique by a physician using a mercury sphygmomanometer, but there is increasing evidence that this may lead to the misclassification of large numbers of individuals as hypertensive and also fail to detect others who are hypertensive outside the clinic setting. In addition, mercury is being banned in many countries, and there is still uncertainty as to what will replace it. Neither the distribution of BP in the population nor the relationship between BP and cardiovascular morbidity provide any justification for a rigid separation between normotension and hypertension, but for clinical purposes, a threshold level of BP above which antihypertensive treatment is recommended needs to be established. Thus, the accurate measurement of BP is of extreme importance.

There are two general reasons for measuring BP. The first is as a “vital sign” when evaluating a critically ill patient, in which case the BP at the time of measurement is of critical interest—is it too high,

normal, or too low? For the vast majority of measurements, however, we are not interested in the pressure at the time of measurement, so much as its ability to estimate the average or “true” level of BP, which is generally assumed to be responsible for the adverse effects of high BP on the circulation and for which the clinic or office BP is taken as a surrogate measure. Recent advances in the techniques of measuring BP, particularly ambulatory monitoring, have begun to provide the opportunity to examine the pathological role of other measures of BP, such as abnormalities of the diurnal rhythm and the short-term variability.

The methods currently available for BP measurement in clinical practice are shown in Figure 1. There are two basic techniques—the auscultatory and oscillometric methods. The former can be done with mercury or aneroid sphygmomanometers, or the more recently introduced hybrid technique. Measurements are preferably taken from the upper arm, although the wrist and finger are alternative sites. In addition, measurements can be taken in the office, at home, or over 24 hours with ambulatory monitoring. The use of all three methods has been endorsed by the seventh national report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7) recommendations.

## TECHNIQUES FOR BP MEASUREMENT

## The Auscultatory Method

It is surprising that nearly 100 years after it was first discovered, and the subsequent recognition of its limited accuracy, the Korotkoff technique for measuring BP has continued to be used without any substantial improvement. The Korotkoff sound method tends to give values for systolic pressure that are lower than the intra-arterial pressure, and diastolic values that are higher, but there is no obvious superiority for phase 5 over phase 4. The official recommendation of

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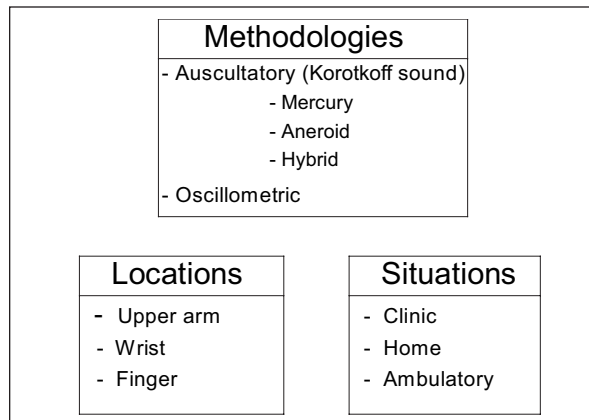


Figure 1. Techniques of blood pressure measurement in clinical practice

organizations such as the American Heart Association is to use the fifth phase, except in children or other situations in which the disappearance of sounds cannot reliably be determined. Most of the large-scale clinical trials that have evaluated the benefits of treating hypertension have used the fifth phase.

**Mercury Sphygmomanometers.** The mercury sphygmomanometer has always been regarded as the gold standard for clinical measurement of BP, but this situation is likely to change in the near future, as discussed below. The design of mercury sphygmomanometers has changed little over the past 80 years, except that modern versions are less likely to spill mercury if dropped. In principle, there is less to go wrong with mercury sphygmomanometers than other devices, but this should not be any cause for complacency, and in practice many mercury devices in clinical use have been found to be defective.

**The Future of Mercury.** A growing trend throughout the world is the removal of mercury-containing devices from hospitals. This has already happened with thermometers and is now happening with sphygmomanometers. The reason is not because a more accurate device has been developed, but because of concerns about the safety of mercury. In some European countries, mercury has already been banned, and there is a growing tendency in the United States to replace mercury devices, although this is being resisted by some organizations. The unresolved issue is what should replace mercury. Currently, the three alternatives are aneroid, electronic (oscillometric), and hybrid. Neither aneroid nor electronic is regarded as satisfactory. Hybrid devices offer the possibility of retaining some of the advantages of the mercury method.

**Aneroid Devices.** The incipient demise of the mercury sphygmomanometer has placed new interest

in alternative methods, of which aneroid devices are the leading contenders. However, surveys conducted in hospitals in the past 10 years have examined the accuracy of the aneroid dials and reported a high rate of inaccuracies.

**Hybrid Devices.** These devices combine the main advantages of the mercury technique while avoiding the use of mercury, by using an electronic transducer in place of the mercury column.

### The Oscillometric Technique

When the oscillations of pressure in a sphygmomanometer cuff are recorded during gradual deflation, the point of maximal oscillation corresponds to the mean intra-arterial pressure. The oscillations begin at approximately systolic pressure and continue below diastolic, so that systolic and diastolic pressure can only be estimated indirectly according to some empirically derived algorithm. One advantage of the method is that no transducer need be placed over the brachial artery, so that placement of the cuff is not critical. Other potential advantages of the oscillometric method for ambulatory monitoring are that it is less susceptible to external noise (but not to low-frequency mechanical vibration) and that the cuff can be removed and replaced by the patient, for example, to take a shower. The main disadvantage is that such recorders do not work well during physical activity, when there may be considerable movement artifact.

The oscillometric technique has been used successfully in ambulatory BP monitors and home monitors. It should be pointed out that different brands of oscillometric recorders use different algorithms, and there is no generic oscillometric technique. However, comparisons of several different commercial models with intra-arterial and Korotkoff sound measurements have shown generally good agreement.

**Validation of Oscillometric Monitors.** The increasing use of electronic monitors for both self-monitoring and ambulatory monitoring has necessitated the development of standard protocols for testing them. The two most widely used have been developed by the British Hypertension Society and Association for the Advancement of Medical Instrumentation (AAMI) in the United States, but there is now an international protocol that requires a smaller number of subjects. One of the limitations of the validation procedures is that they analyze the data on a population basis and pay no attention to individual factors. Thus, it is possible that a monitor will pass the validation criteria and still be consistently in error in a substantial number of individuals. An up-to-date survey of validated

monitors is available on the dabl Educational Trust Web site (<http://www.dableducational.com/>).

#### Technical Issues With Measurement From the Arm

There are important potential sources of error with measurements from the upper arm, which are listed below.

**Effects of Posture.** BP measurement is most commonly made in either the sitting or supine position, but the two positions give different measurements. Diastolic pressure measured while sitting is higher than when measured supine (by about 5 mm Hg), but systolic pressure is the same. Other considerations include the position of the back and legs. If the back is not supported (as when the patient is seated on an examination table as opposed to a chair), the diastolic pressure may be increased by 6 mm Hg. Crossing the legs may raise systolic pressure by a similar amount. When measurements are taken in the supine position, the arm should be supported with a pillow.

BP measurements are also influenced by the position of the arm. There is a progressive increase in the pressure of about 5 mm Hg as the arm is moved down from the horizontal to vertical position. These changes are exactly what would be expected from the changes of hydrostatic pressure.

**Cuff Size.** The size of the cuff relative to the diameter of the arm is critical. The commonest mistake is to use a cuff that is too small, which will result in an overestimation of the pressure. In general, the error can be reduced by using a large adult-sized cuff for all except the skinniest arms.

**Rate of Cuff Inflation and Deflation.** The rate of inflation has no significant effect on the BP, but with very slow rates of deflation ( $\leq 2$  mm Hg/sec), the intensity of the Korotkoff sounds was diminished, resulting in slightly higher diastolic pressures. This effect has been attributed to venous congestion reducing the rate of blood flow during very slow deflation. The recommended deflation rate is 2–3 mm Hg/sec.

#### BP Measurement in the Office

Although the mercury method is still considered the gold standard for measurement in the clinic, there is a huge gulf between the ideal measurements and those made in real life. The recent interest in alternative methods of measuring BP has served to emphasize some of the potentially correctable deficiencies of the routine clinic measurement of BP. By increasing the number of readings taken per visit and the number of visits, as well as by attempting to eliminate sources of error such as terminal digit preference, the reliability of clinic pres-

sure for estimating the true BP and its consequences can be greatly increased. However, a number of factors relating to the physician, the patient, or their interaction may lead to either over- or under-estimation of the true BP. Some of these are listed in Table I.

#### Sources of Error in Office Measurements

**Observer Error.** Observer error and observer bias are important sources of error when conventional sphygmomanometers are used. Differences of auditory acuity between observers may lead to consistent errors, and terminal digit preference is very common, with most observers recording a disproportionate number of readings ending in 5 or 0.

**Patient-Related Factors.** If the patient is very anxious, talks during the BP measurement, or has just smoked a cigarette or drunk coffee, the recorded pressure may overestimate the true pressure. Conversely, if the patient smokes during the day, is very physically active, or has a stressful job, the clinic pressure may underestimate the true pressure.

**The White Coat Effect.** One of the main reasons for the growing disillusion of the value of traditional office BP readings is the white coat effect, which is conceived as the increase of BP that occurs at the time of a clinic visit and dissipates soon thereafter. It has been known for more than 50 years that BPs recorded by a physician can be as much as 30 mm Hg higher than pressures taken by the patient at home, using the same technique and in the same posture. Physicians also record higher pressures than nurses or technicians. The white coat effect is usually defined as the difference between the clinic and daytime ambulatory pressure. The underlying mechanisms are not well understood, but may include anxiety, a hyperactive alerting response, or a conditioned response. The white coat effect is seen to a greater or lesser extent in most if not all hypertensive patients, but is much smaller or negative in normotensive subjects or those with masked hypertension. A closely linked but discrete entity is white coat hypertension, which refers to a subset of patients who are hypertensive according to their clinic BPs but normotensive at other times.

**Use of Oscillometric Monitors in the Office.** One way of reducing observer error and increasing the number of readings is to use an oscillometric device that can be programmed to take multiple readings while the patient is seated in the waiting room.

These devices may also reduce the white coat effect to some extent. The BP levels tend to be lower than the physician's readings, but it is not yet clear how well they correlate with other measures.

**Table I.** Patient- and Physician-Related Factors That Lead to a Discrepancy Between the Clinic and True Blood Pressure (BP)

	CLINIC BP OVERESTIMATES TRUE BP	BIDIRECTIONAL ERROR	CLINIC BP UNDERESTIMATES TRUE BP
Physician	Observer error Cuff size too small	Observer error	Observer error Cuff size too large
Patient	Anxiety Talking Recent ingestion of pressor substances	Spontaneous BP variability	Smoker Physically active during day Stressful job
Physician-patient interaction	White coat effect Positive		White coat effect Negative
Possible diagnosis	White coat hypertension		Masked hypertension

### Self-Monitoring of BP (SMBP)

The potential advantages of having patients take their own BP are two-fold: the distortion produced by the white coat effect is eliminated, and multiple readings can be taken over prolonged periods of time. SMBP plays an increasing role in the diagnosis of hypertension. It may be used as a first step in the evaluation of patients with suspected white coat hypertension, as recommended in JNC 7. There are two studies that have compared the predictive value of clinic and home measurements, and both have shown that home measurements are potentially superior. In the first, which was conducted as a population survey in the town of Ohasama, Japan, 1789 people were evaluated with home, clinic, and 24-hour BP measurements. Over a 5-year follow-up, it was found that the home pressure predicted risk better than the clinic readings. The second study, which was conducted in France and recruited 4939 elderly hypertensives who were currently on treatment, found that morbid events observed over a 3.2 year follow-up period were predicted by the home BP at baseline but not by the clinic pressure. One particularly interesting aspect of this study was that patients who had normal clinic pressures but high home pressures were at increased risk, a phenomenon known as masked hypertension.

There is also evidence that SMBP can improve BP control; a recent meta-analysis of 18 randomized trials comparing SMBP with usual care found that BP control was improved by about 4/2 mm Hg in the SMBP groups. One of the strongest arguments for using SMBP to assess the response to antihypertensive treatment comes from the Italian Study on Ambulatory Monitoring of BP and Lisinopril Evaluation (SAMPLE) study, which used three methods of BP measurement (clinic, ambulatory, and SMBP) to relate the changes in BP resulting from treatment with an angiotensin-converting enzyme inhibitor to the regression of left ventricular hypertrophy. The changes of clinic pressure showed no significant correlation with the changes in left ventricular mass, whereas both SMBP and ambulatory monitoring did show correlations. The implication of this finding is that when there is a discrepancy between the effects of

antihypertensive drug treatment on clinic and home-measured BP, the latter may be more meaningful.

While exclusive reliance on self-monitored readings is not recommended, they can provide a useful adjunct to clinic readings, both for the initial evaluation of newly diagnosed patients and for monitoring their response to treatment. The relative advantages of clinic, self, and ambulatory monitoring are shown in Table II.

### Electronic Monitors for SMBP

When home monitoring was first used, the majority of studies used aneroid sphygmomanometers. In the past few years automatic electronic devices have become increasingly popular and reliable, and are now recommended. The standard type of monitor for home use is now an oscillometric device, which records pressure from the brachial artery. Oscillometric monitors have the advantage of being easy to use, since cuff placement is not as critical as with devices that use a Korotkoff sound microphone, and in practice the oscillometric method has been found to be as reliable as the Korotkoff sound method.

There is now a large number of monitors on the market, but not all have been validated. Those that have are reviewed on the *dabl* Web site and only those that have satisfied the criteria should be used. The advantages of electronic monitors have begun to be appreciated by epidemiologists, who have always been greatly concerned about the accuracy of clinical BP measurement and have paid much attention to the problems of observer error, digit preference, and the other causes of inaccuracy described above. Electronic devices that can take BP from the upper arm, wrist, or finger are now available. While the use of the more distal sites may be more convenient, measurement of BP from the arm (brachial artery) has always been the standard method and is likely to remain so for the foreseeable future.

**Wrist Monitors.** Wrist monitors have the advantages of being smaller than the arm devices and can be used in obese people, since the wrist diameter is little

affected by obesity. A potential problem with wrist monitors is the systematic error introduced by the hydrostatic effect of differences in the position of the wrist relative to the heart. This can be avoided if the wrist is always at heart level when the readings are taken, but there is no way of knowing retrospectively whether this was complied with when a series of readings are reviewed. Wrist monitors have potential, but need to be evaluated further.

**Finger Monitors.** Finger monitors are convenient, but have so far found to be inaccurate and are not recommended.

### Ambulatory BP Monitoring (ABPM)

First developed more than 40 years ago, ambulatory blood pressure monitoring (ABPM) is only now beginning to find acceptance as a clinically useful technique. Technological advances over the past few years have led to the introduction of monitors that are small, relatively quiet, and can take up to 100 readings of BP over 24 hours while patients go about their normal activities. They are reasonably accurate while the patient is at rest, but less so during physical activity. In theory, they can provide information about the three main measures of BP—the average level, the diurnal variation, and short-term variability. Because the currently available monitors take readings intermittently rather than continually and are unreliable during exercise, they can only give a very crude estimate of the short-term variability of BP. Recordings in hypertensive patients show that in the majority of patients the average ambulatory pressure is lower than the clinic pressure, and in some cases may be within the normal range, leading to a diagnosis of white coat hypertension, described below.

### Diurnal Rhythm of BP

There is a pronounced diurnal rhythm of BP, with a decrease of 10–20 mm Hg during sleep and a prompt increase on waking and getting up in the morning. The highest BPs are usually seen between 6 a.m. and noon, which is the time at which the prevalence of many cardiovascular morbid events tends to be highest. The pattern of BP during the day is largely dependent on the pattern of activity, with pressures tending to be higher during the hours of work and lower while at home. In hypertensive patients, the diurnal BP profile is reset at a higher level of pressure, with preservation of the normal pattern in the majority. The short-term BP variability is increased when expressed in absolute terms (mm Hg), but the percentage changes are no different. Thus hypertension can be regarded as a disturbance of the set point or

**Table II.** Value of Different Methods of Blood Pressure Measurement in Clinical Practice

UTILITY	METHOD OF BLOOD PRESSURE MEASUREMENT		
	CLINIC (MM HG)	SELF (MM HG)	AMBULATORY (MM HG)
Predicts outcome	+	+	++
Diagnostic use	+	+	++
Normal limit	140/90	135/85	135/85 (day)
Evaluation of treatment	+	++	+
Improves adherence	-	+	-

tonic level of BP with normal short-term regulation. Antihypertensive treatment reverses these changes, again by resetting the set-point towards normal, with little effect on short-term variability.

### ABPM for Predicting Risk

Given that there is a discrepancy between the clinic and ambulatory pressure, it is reasonable to suppose that the prediction of risk will be different. There are now many cross-sectional studies relating the extent of cardiovascular damage to both clinic and ambulatory pressures. Almost all have shown that the correlation coefficients are higher for ambulatory pressure, although in many instances the differences were small. The superiority of ambulatory pressure in this respect may be attributed at least in part to the greater number of readings, and to their more representative nature.

There are now 10 prospective studies comparing the prediction of cardiovascular events using clinic or ambulatory BP, and the overwhelming consensus is that ambulatory pressure is a better predictor of risk than clinic pressure. Thus, when the ambulatory pressure is low in comparison to the clinic pressure (white coat hypertension) the prognosis is benign. This body of data was what led to the decision by The Centers for Medicare and Medicaid Services to approve ABPM for reimbursement in patients with suspected white coat hypertension because they comprise a low-risk group that does not necessarily need antihypertensive drug treatment. One study looked at patients with refractory hypertension, defined as a diastolic pressure >100 mm Hg while on three or more antihypertensive medications. Patients were classified in three groups according to their daytime ambulatory pressure; those in the lowest tertile (<88 mm Hg) had a significantly lower rate of morbidity over the next 4 years, despite similar clinic pressures. An important study in this series was the Systolic Hypertension in Europe (Syst-Eur) trial, a large

<b>Table III.</b> Accepted and Potential Clinical Indications for Ambulatory Blood Pressure Monitoring (ABPM)
CLINICAL INDICATIONS FOR ABPM
ACCEPTED INDICATIONS
Suspected white coat hypertension Suspected nocturnal hypertension Suspected masked hypertension To establish dipper status Resistant hypertension Hypertension of pregnancy
POTENTIAL INDICATIONS
Elderly patients As a guide to antihypertensive drug treatment Type I diabetes Evaluation of symptoms suggesting orthostatic hypotension Autonomic failure
From O'Brien E, Asmar R, Beilin L, et al. Practice Guidelines of the European Society of Hypertension for Clinic, Ambulatory, and Self Blood Pressure Measurement. <i>J Hypertens</i> . In press.

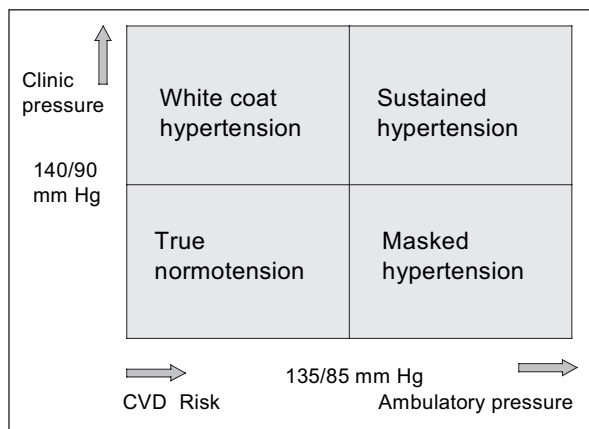


Figure 2. Classification of blood pressure status according to office and out-of-office measurements. CVD=cardiovascular

placebo-controlled study of the effects on cardiovascular morbidity of treating systolic hypertension of the elderly with a calcium channel blocker. A substudy of 808 patients used ABPM and found that ABPM was a much more potent predictor of risk than office BP. This study is the only one that has examined the effects of treating patients with white coat hypertension because there was a placebo group as well as an active treatment group. There was a significant reduction of events in the active treatment group in patients with sustained hypertension but not in the group with white coat hypertension.

The main use of ABPM is for the initial diagnosis of a patient's BP status, as shown in Table II. It is of limited value for the evaluation of treatment. Some specific diagnostic indications where ABPM is useful are shown in Table III.

## CLASSIFICATION OF HYPERTENSION USING OUT-OF-OFFICE MEASUREMENT

With the combined use of BP measurement in and out of the office, BP status can be classified differently from the traditional one-dimensional method based solely on clinic pressures. As shown in Figure 2, the cutoff points for clinic and daytime ambulatory BPs are different—140/90 mm Hg for the former and 135/85 for the latter. There are four cells—true normotension (normotensive by both criteria), true hypertension (hypertensive by both), white coat hypertension (hypertensive by clinic criteria, normotensive by ambulatory), and masked hypertension (normotensive in the clinic and hypertensive during ambulatory monitoring). As also shown in the Figure, the current evidence indicates that the degree of cardiovascular risk goes with the ambulatory rather than the clinic pressure.

### White Coat Hypertension

White coat hypertension is defined as a persistently elevated clinic pressure (>140/90 mm Hg) together with a normal daytime ambulatory pressure ( $\leq$ 135/85). It is important to emphasize that it requires several clinic visits to establish the diagnosis because there may be a spontaneous decline of clinic pressure with multiple visits. White coat hypertension is not a discrete entity, since most hypertensive patients show a white coat effect. What distinguishes patients with white coat hypertension from those with true or sustained hypertension is not that they have an exaggerated white coat effect, but that their BP is within the normal range when they are outside the clinic setting. Patients with white coat hypertension do not necessarily look anxious or have a tachycardia while in the office. Thus, it can only be diagnosed reliably by ambulatory monitoring. If patients with white coat hypertension are treated with antihypertensive drugs there is typically a decline of clinic pressure but little or no change of ambulatory pressure, which by definition is normal to start with.

### Masked Hypertension

As mentioned above, there are some patients in whom the white coat effect is negative and in whom clinic pressure may significantly underestimate the BP measured outside. The importance of this, which is referred to as masked hypertension, is that there is increasing evidence that such individuals have more target organ damage and higher risk of cardiovascular disease than patients who are normotensive both in and out of the office.

### Dipping Status

Another way of classifying patients using ambulatory monitoring is by the change of BP during the

night. The normal “dipping” pattern is defined as a difference between the average daytime and nighttime BP of at least 10 mm Hg; in about 25% of hypertensive patients (non-dippers), the nocturnal fall of BP is smaller or absent. Non-dipping is more common in African Americans than in whites and is a feature of a number of pathological conditions, including malignant hypertension, chronic renal failure, the metabolic syndrome, and conditions such as diabetes that are associated with autonomic neuropathy. The non-dipping pattern has been associated with increased cardiovascular risk in several studies. Antihypertensive drug treatment may convert non-dippers to dippers in some cases.

### Morning Surge of BP

Most cardiovascular events occur in the morning hours between 6 a.m. and noon, and there is recent evidence that the morning surge of BP that occurs on waking and getting up may be related to an increased risk of strokes. Thus, it is important that long-acting antihypertensive drugs be used to ensure that there is adequate BP control during the early morning hours. The use of self-monitored BP readings taken on waking and at night may give a good guide to the morning surge.

### How Should the Different Techniques of Measurement Be Used?

For the immediate future, measurement of clinic BP by conventional sphygmomanometry will continue to be the principal method of clinical evaluation. A cardinal rule is that the closer the BP is to the threshold level at which treatment will be started, the more readings should be taken over more visits, before the decision is made. In patients who have persistently elevated clinic pressure and evidence of BP-related target organ damage, it is usually unnecessary to supplement the clinic readings with other types of measurement before reaching a therapeutic decision. When an elevated BP is the only detectable abnormality, however, the possibility that the clinic pressure may overestimate the true pressure should be considered. This can be done either by self-monitoring or by ambulatory monitoring. A schema for the use of the different procedures for measuring BP when evaluating a newly diagnosed hypertensive patient is shown in Figure 3. If self-monitoring is chosen and reveals pressures comparable to the clinic, value treatment may be appropriate, but if the home readings are much lower than the clinic readings, it does not rule out the possibility that the BP may be elevated at work. This is the advantage

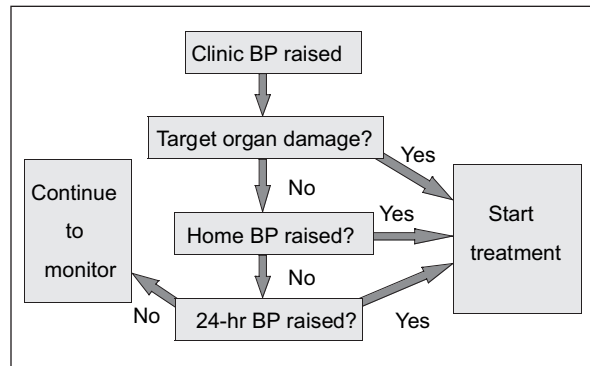


Figure 3. Schema for the evaluation of hypertensive patients using office (clinic) and out-of-office measurement. BP=blood pressure

of ambulatory monitoring, which gives the best estimate of the full range of BP experienced during everyday life.

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