Evidence based treatment of hypertension

Measurement of blood presssure: an evidence based review

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This is the first in a series of five articles on the treatment of hypertension

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The reasons for routinely measuring blood pressures in adults are evident. Raised blood pressure is a common condition that does not have specific clinical manifestations until target organ damage develops. It confers a substantial risk of cardiovascular disease (particularly in the presence of concomitant risk factors), much of which is at least partially reversible with treatment. Finally, screening adults to detect hypertension early and initiate treatment before the onset of target organ damage is highly cost effective.[1]

Accurate measurement is of paramount importance. For example, consistently underestimating the diastolic pressure by 5 mm Hg could result in almost two thirds of hypertensive individuals being denied potentially lifesaving—and certainly morbidity preventing—treatment[2]; consistently overestimating it by 5 mm Hg could more than double the number of individuals diagnosed as hypertensive (half of whom would be inappropriately labelled and treated).[2]

Summary points

- The accurate measurement of blood pressure in clinic settings is of paramount importance
- Guidelines for its measurement should be followed, particularly when it is newly detected or the patient has cardiovascular target organ damage, other atherosclerotic risk factors, or is receiving antihypertensive treatment
- Evidence regarding factors which distort blood pressure readings and the magnitude of their effect is generally weak, but factors shown in high quality studies to be able to affect readings by more than 5 mm Hg include talking, acute exposure to cold, recent ingestion of alcohol, incorrect arm position, and incorrect cuff size
- The white coat effect can raise blood pressure more than 20/10 mm Hg in up to 40% of patients
- The benefits and cost effectiveness of self measurement or ambulatory monitoring are still under investigation, but they should be considered for the evaluation of suspected white coat hypertension, apparent drug resistance, episodic hypertension, suspected autonomic dysfunction, or a hypotensive reaction to antihypertensive treatment

What can interfere with the accuracy of blood pressure measurement?

Most people's blood pressure varies substantially throughout the day. Lowest readings occur during rest or sleep, while a variety of activities cause an increase (table 1). Additionally, numerous factors can affect the accuracy of measurements (table 2).[3-9] A comprehensive literature search identified all studies describing potential sources of bias in measurement of blood pressure. The studies were evaluated using a standard hierarchy of evidence (that of the Centre for Evidence-Based Medicine; http://cebm.jr2.ox.ac.uk/docs/levels.html), and table 2 shows those factors which evaluated satisfactorily against a "gold standard." Full listings of the search strategy and references, all factors which have been described, and the supporting evidence behind each factor are given in *Evidence Based Hypertension*.[10]

In a survey of 114 doctors the most common mistakes included use of an inappropriately sized cuff (97%), failure to allow a rest period before measurement (96%), deflating the cuff too fast (82%), not measuring in both arms (77%), and failure to palpate maximal systolic pressure before auscultation (62%).[11]

How should we measure blood pressure clinically?

Virtually all published guidelines agree on how to measure blood pressure clinically (box).[12] A few points deserve emphasis. Firstly, as there are pressure differences of more than 10 mm Hg between the arms in 6% of hypertensive patients[13] the pressure should be measured in both arms at initial assessment and the arm with the higher pressure used subsequently. Secondly, the phase V Korotkoff sound should be used because it more closely matches the true diastolic pressure defined by direct arterial monitoring, is more reproducible between observers, and has been used as the standard in the randomised clinical trials which have established the benefits of antihypertensive treatment. Thirdly, although aneroid sphygmomanometers are more popular than mercury instruments, they require regular calibration and checks for common defects such as non-zeroed gauges, cracked face plates, or defective rubber tubing. Finally, busy clinicians are frequently discouraged by the time and effort needed to measure blood pressure as meticulously as recommended in guidelines, though it is debatable whether this degree of rigour is always necessary. As Reeves points out: "if all serious errors that can underestimate BP are avoided … the efficient practitioner can reasonably reserve the 'proper' method for the 10% to 20% of patients who have known or newly detected elevated BP… cardiovascular target organ damage, other risk factors, or are receiving antihypertensive therapy."[14]

What is the "white coat effect"?

Blood pressures measured in the clinic by medical staff are generally similar to usual readings in normotensive people, but discrepancies are often seen in patients with hypertension.[15] Indeed, almost 20% of patients diagnosed as hypertensive on the basis of readings in the clinic have entirely normal ambulatory pressures ("white coat hypertensives")—including 4% of patients with clinic readings ≥180/110 mm Hg.[15] Although it is difficult to be certain in the absence of high quality diagnostic studies, up to 40% of patients with hypertension may show white coat effects of more than 20/10 mm Hg.[14]

Guidelines for measuring blood pressure in adults (adapted from Perloff et al[12])

- Seat the patient in a quiet, calm environment with a bared arm resting on a standard table or other support so the midpoint of the upper arm is at the level of the heart
- Estimate the circumference of the bare upper arm at the midpoint between the shoulder and the elbow, by inspection or tape measure, and select an appropriate cuff. The bladder inside the cuff should encircle 80% of the arm
- Place the cuff so that the midline of the bladder is over the arterial pulsation, then wrap and secure the cuff snugly around the subject's bare upper arm
- The lower edge of the cuff should be 2.5 cm above the antecubital fossa where the head of the stethoscope is to be placed
- Inflate the cuff rapidly to 70 mm Hg and then by 10 mm increments while palpating the radial pulse. Note the reading at which the pulse disappears and subsequently reappears during deflation
- Place the low frequency head (bell) of your stethoscope over the brachial artery pulsation
- Inflate the bladder rapidly and steadily to a pressure 20-30 mm above the level previously determined by palpation, then allow the bladder to deflate at 2 mm/sec while listening for the appearance of the Korotkoff sounds
- As the pressure in the bladder falls, note the manometer readings at the first appearance of repetitive sounds (phase I), at the muffling of these sounds (phase IV), and when they disappear (phase V). As long as the Korotkoff sounds are audible, the rate of deflation should be no more than 2 mm per pulse beat
- After the last Korotkoff sound is heard, the cuff should be deflated slowly for at least another 10 mm to ensure that no further sounds are audible, and then rapidly and completely deflated; the subject should then be allowed to rest for 30 seconds
- The systolic (phase I) and diastolic (phase V) pressures should be recorded immediately, to the nearest 2 mm Hg
- The measurement should be repeated after at least 30 seconds have elapsed, and the two readings averaged. In clinical situations additional measurements may be made in the same or opposite arm, in the same or an alternative position
- Multiple visits are needed before the diagnosis of hypertension can be established; their exact number and frequency will depend on how much the blood pressure is raised and whether there are other cardiovascular risk factors

Table 1 Effects of routine activities on blood pressure (adapted from Campbell et al[2])

Activity	Effect on blood pressure (mm Hg)	
	Systolic blood pressure	Diastolic blood pressure
Attending a meeting	↑ 20	↑ 15
Commuting to work	↑ 16	↑ 13
Dressing	↑ 12	↑ 10
Walking	↑ 12	↑ 6
Talking on telephone	↑ 10	↑ 7
Eating	↑ 9	↑ 10
Doing desk work	↑ 6	↑ 5
Reading	↑ 2	↑ 2
Watching television	↑ 0.3	↑ 1

Table 2 Factors that can interfere with the accuracy of blood pressure measurement

Factor	Measured *v* actual blood pressure*		Highest quality of evidence†
	Systolic blood pressure	Diastolic blood pressure	
Patient			
Talking	↑ 17 mm Hg	↑ 13 mm Hg	Level 1[3]
Acute exposure to cold	↑ 11 mm Hg	↑ 8 mm Hg	Level 2[4]
Acute ingestion of alcohol	↑ 8 mm Hg for ≤3 hrs	↑ 7 mm Hg for ≤3 hrs	Level 1[5]
Technique			
Patient supine rather than sitting	No effect;↑ 3 mm Hg in supine position	↓ 2-5 mm Hg in supine position	Level 1[6]
Position of patient's arm	↓ (or ↑) 8 mm Hg for every 10 cm above (or below) heart level	↓ (or ↑) 8 mm Hg for every 10 cm above (or below) heart level	Level 1[7]
Failure to support arm	↑ 2 mm Hg	↑ 2 mm Hg	Level 1[7]
Cuff too small	↓ 8 mm Hg	↑ 8 mm Hg	Level 1[8]
Measurer			
Expectation bias (including end digit preference)	Rounding to nearest 5 or 10 mm Hg	Rounding to nearest 5 or 10 mm Hg	Level 1[9]

*Mean values obtained from referenced studies.
†Using levels of evidence for diagnostic studies.

Although the white coat effect may be more pronounced in older people than in younger people and in women than in men, it is impossible to diagnose white coat hypertension or the white coat effect on clinical examination alone.[16] Clues to the presence of the white coat effect include persistently raised clinic readings in the absence of hypertensive damage to target organs, raised clinic readings with symptoms suggesting postural hypotension, or marked discrepancy between readings obtained in the clinic and those found in other settings.

Evidence on whether patients with white coat hypertension are at higher cardiovascular risk than normotensive individuals is conflicting. Although cross sectional studies and early small cohort studies suggested excess risk, two large cohort studies failed to find any excess cardiovascular risk in patients with isolated white coat hypertension.[17 18] While such patients may subsequently develop persistent hypertension, few studies have investigated whether treatment to lower their pressures measured in the clinic reduces progression to sustained hypertension or cardiovascular end points.

How well do clinic measurements reflect "true" blood pressure?

Assuming that the office technique is correct and none of the factors outlined in tables 1 or 2 are operative, further sources of error may still arise.

Firstly, there may be substantial discrepancy between the Korotkoff sounds and corresponding

intra-arterial readings. While indirect pressure findings correlate well with the intra-arterial readings, the Korotkoff phase I sounds do not appear until an average of 3 mm Hg below the direct systolic pressure, and the phase V sounds disappear an average of 9 mm Hg higher than the direct diastolic pressure (evidence from level 1 studies).[19] Unfortunately, these discrepancies are not the same in all patients, and blood pressures measured indirectly in elderly patients with sclerotic arterial walls may appear substantially higher than the true intra-arterial pressures ("pseudohypertension").

Secondly, readings made in the clinic may not reflect the blood pressure over a 24 hour period as there is marked variation over time: standard deviations as high as 12/8 mm Hg may be seen when a patient's pressure is taken on different days.[20] Furthermore, owing to habituation and regression to the mean, blood pressure generally falls with repeated measurement. Thus, use of a single measurement to define a patient's blood pressure would overdiagnose hypertension in 20-30% of the population and miss a third of those who are truly hypertensive.[14 21]

What is the role of home self monitoring?

Having patients take their own blood pressure regularly at home has potential advantages: multiple readings can be obtained over a prolonged period of time (allowing better definition of true pressure) and, as no medical staff are involved, any distortions due to the white coat effect should be eliminated. The high specificity of self measurement in detecting the white coat effect (85% in a study of 189 subjects with high clinic readings) suggests it is reasonable for use as a screening test and for the long term follow up of patients with white coat hypertension or of treated hypertensive patients with known white coat effect.[22]

However, there are some potential disadvantages. Firstly, there is a greater potential for errors in measurement (due to inadequate training of patients and the inaccuracy of many home electronic monitors).[15] Secondly, there is inadequate standardisation of self monitoring of blood pressure at home and lack of consensus about the reference values for it. Furthermore, although preliminary data suggest that home pressures correlate more closely with cardiovascular mortality than do those found in the clinic,[23] the lack of large scale prospective data on the point limits the usefulness of self monitoring. A randomised trial comparing home management of hypertension with usual care showed reductions in blood pressure, in number of office visits related to hypertension, and in costs of care in the intervention group, but none was significant.[24]

Table 3 Blood pressure during ambulatory monitoring (adapted from Ohkubo et al[32])

	Probably normal	Borderline	Probably abnormal
Systolic average (mm Hg)			
Awake	<135	135-140	>140
Asleep	<120	120-125	>125
24 hour	<130	130-135	>135
Diastolic average (mm Hg)			
Awake	<85	85-90	>90
Asleep	<75	75-80	>80
24 hour	<80	80-85	>85
Load*			
Systolic	<15%	15-30%	>30%
Diastolic	<15%	15-30%	>30%

*Percentage of ambulatory blood pressure measurements above threshold (140/90 mm Hg awake and 120/80 mm Hg nocturnal).

What is the role of ambulatory blood pressure monitoring?

Ambulatory blood pressure monitoring permits the non-invasive measurement of blood pressure over a prolonged period (usually 24 hours). It has become increasingly popular in the assessment of hypertensive patients as it provides a more reproducible estimate of an individual's pressure and is relatively free from side effects.[25]

Multiple cross sectional studies have confirmed that ambulatory readings correlate better than clinic findings with the presence of damage to target organs. Virtually all these studies investigated the association between ambulatory readings and left ventricular mass—a surrogate marker strongly predictive of future cardiovascular events. Although the literature on the ability of ambulatory monitoring to predict cardiovascular risk is not as large and consistent as that for observations made in the clinic, available data suggest that ambulatory monitoring provides more information of use in determining prognosis than can be derived from clinic readings.[17 18 26-28] The accuracy of ambulatory monitoring in predicting cardiovascular risk depends on the reproducibility of the measurements obtained; in almost a third of subjects monitored, however, mean blood pressure differed by 7 mm or more from day to day.[29] In a recent study of 233 subjects, multiple readings taken in clinic but not by doctors correlated closely with ambulatory results and were just as highly associated with albuminuria and left ventricular hypertrophy.[30]

Although most essential hypertensive patients are "dippers" (mean nocturnal pressure $\geq$10 mm Hg lower than that in daytime), continuous monitoring identifies a subgroup as "non-dippers," who seem to have more target organ damage and higher cardiovascular morbidity and mortality rates than dippers, even after adjustment for age, sex, other cardiovascular risk factors, and baseline blood pressure.[18 27 28] However, caution must be exercised in applying this evidence, as the division of patients into dippers and non-dippers is arbitrary and dipping status cannot be reproduced easily. For example, of 253 untreated hypertensive patients monitored for 48 hours, only 71% were classified (as dippers or non-dippers) similarly on consecutive days.[31]

As with clinic measurements, there is debate over the normal range for ambulatory readings. Table 3 outlines values, validated in a high quality cohort study, representing the points at which hypertensive damage to target organs begins to develop.[32 33]

The final (and most important) issue is when should ambulatory monitoring be used. Although its use in all individuals suspected of being hypertensive would reduce the frequency of misdiagnosis, this would lead to a tremendous drain on available resources. Ambulatory monitoring may be most useful in evaluating patients with suspected white coat hyper-

tension (as shown by high readings in the clinic but no signs of target organ damage), apparent drug resistance, episodic hypertension, suspected autonomic dysfunction, and development of hypotensive symptoms when they are being treated with an antihypertensive drug.[33] A number of randomised trials investigating the role of ambulatory monitoring in management of antihypertensive treatment are in progress. The first of these (in 419 subjects) has shown that, when management is based on ambulatory pressures rather than clinic readings, the need for intensive drug treatment is reduced without detriment to blood pressure control, left ventricular mass, or general wellbeing.[34] The cost effectiveness of this approach is still being investigated.

In conclusion, the accurate measurement of blood pressure in the clinic is a vital component in the assessment and modification of cardiovascular risk. Home and ambulatory measurements may be important in the investigation of some hypertensive individuals, but clinic findings remain the evidentially based yardstick for the care of these patients.

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One hundred years ago

A temperance experiment

The scheme for reforming public-houses, usually spoken of as Earl Grey's Public-house Trust Scheme, owing to the share which he has taken in at least one practical application, is well deserving of study, and the experiments now to be tried on a large scale in parts of Great Britain will be watched with interest by all those who believe that temperance may best be encouraged by diminishing the temptations to drink. It seems only reasonable to hope that good will result from a scheme, which will bring about a diminution of the public-houses of the existing "gin-palace" type, and their replacement by refreshment rooms where wholesome food at popular prices, and tea, coffee, etc., can be obtained as easily as alcoholic drinks; where likewise the crowded drinking bar will be largely replaced by seats and tables at which customers can eat as well as drink in comfort. The proprietors or managers of ordinary public-houses are encouraged to push the sale of alcoholic drinks in preference to tea, coffee, and ordinary refreshments on account of the larger profits to be obtained from intoxicating liquors. In country villages it is suggested that the houses of the Public-house Trust should have club, recreation, and reading rooms, as well as the old-fashioned bowling green and other outdoor counter-attractions to the tap-room.

(*BMJ* 1901;ii:158)