ABC of hypertension
Blood pressure measurement
Part I—Sphygmomanometry: factors common to all techniques

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Methods of blood pressure measurement

Most devices for measuring blood pressure are dependent on one common feature, namely, occluding the artery of an extremity (arm, wrist, finger, or leg) with an inflatable cuff to measure blood pressure either oscillometrically, or by detection of Korotkoff sounds. Other techniques, which are not dependent on limb occlusion, such as pulse-waveform analysis, can also be used, but these have little application in clinical practice. The array of techniques available today owe their origins to the conventional technique of auscultatory blood pressure measurement, and these new techniques must indeed be shown to be as accurate as the traditional mercury sphygmomanometer. Since the introduction of sphygmomanometry, mercury and aneroid sphygmomanometers have been the most popular devices for measuring blood pressures.

Mercury sphygmomanometer

Factors affecting blood pressure measurement

No matter which device is used to measure blood pressure, it must be recognised that blood pressure is a variable haemodynamic phenomenon, which is influenced by many factors, not least being the circumstances of measurement itself. These influences on blood pressure can be significant, often accounting for rises in systolic blood pressure greater than 20 mm Hg, and if they are ignored, or unrecognised, hypertension will be diagnosed erroneously and inappropriate management instituted. These factors have to be carefully considered in all circumstances of blood pressure measurement—self measurement by patients, conventional measurement, measurement with automated devices whether in a doctor's surgery, an ambulance, a pharmacy, or in hospital using sophisticated technology.[1 2]

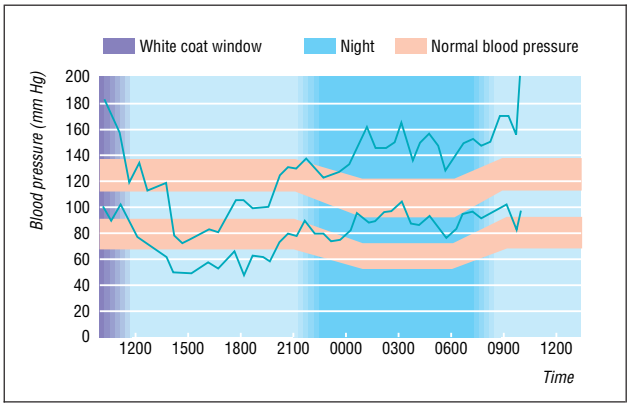
Important factors affecting measurement

- The inherent variability of blood pressure
- The defence reaction
- The limitations of the device being used
- The accuracy of the device
- Blood pressure is not as easily measured in some groups, such as elderly people

Variability of blood pressure

The observer must be aware of the considerable variability that may occur in blood pressure from moment to moment with respiration, emotion, exercise, meals, tobacco, alcohol, temperature, bladder distension, and pain, and that blood pressure is also influenced by age, race, and circadian variation. It is usually at its lowest during sleep. It is not always possible to modify these many factors but we can minimise their effect by taking them into account in reaching a decision as to the relevance or otherwise of a particular blood pressure measurement.[1]

Insofar as is practical the patient should be relaxed in a quiet room at a comfortable temperature and a short period of rest should precede the measurement. When it is not possible to achieve optimum conditions, this should be noted with the blood pressure reading—for example, "BP 154/92, R arm, V phase (patient very nervous)."



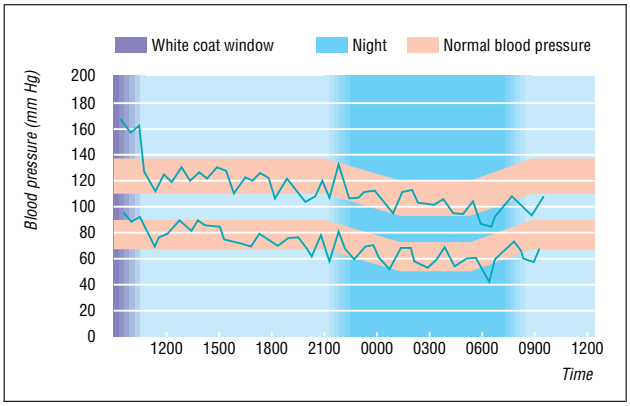
Example of a normal ambulatory blood pressure pattern plotted by the DABL® Program showing a marked variability of blood pressure

"White coat" hypertension

Anxiety raises blood pressure, often by as much as 30 mm Hg. This may be regarded as a physiological reaction, often referred to as the "fight and flight" phenomenon, or "defence" or "alarm" reaction. It is commonly seen in the accident and emergency departments of hospitals when patients are frightened and extremely anxious, but it may also occur in family doctors' surgeries and in the outpatients department. It may occur in normotensive and hypertensive subjects. The degree of this reaction varies greatly from patient to patient, being absent in many, and it is usually reduced or abolished altogether with reassurance and familiarisation with the technique and circumstances of blood pressure measurement. Its importance in practice is that decisions to lower blood pressure, and especially to administer drugs, should never be made on the basis of measurements taken in circumstances where the defence reaction is likely to be present.

White coat hypertension is a condition in which a normotensive subject becomes hypertensive during blood pressure measurement, but pressures then settle to normal outside the medical environment. It is best demonstrated by ambulatory blood pressure measurement (ABPM).

No one group seems to be exempt from the white coat phenomenon; it may affect the young, the elderly, normotensive and hypertensive subjects, and pregnant women. In young subjects with borderline elevation of conventional blood pressure, identification of white coat hypertension can be of considerable importance in avoiding undue penalties for insurance and employment. Moreover, there are no characteristics that allow for the identification of the phenomenon, other than by obtaining blood pressures away from the medical environment, either by self measurement in the home or with ABPM, which is the technique of choice. Patients diagnosed as "hypertensive" with conventional measurement in whom white coat hypertension is considered a possibility should have ABPM performed before they are labelled "hypertensive," and certainly before treatment is instigated.



White coat hypertension

Patient in standard seated position

Posture of subject

Posture affects blood pressure, with a general tendency for it to increase from the lying to the 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. None the less, it is advisable to standardise posture for individual patients and in practice blood pressure is usually measured in the sitting position. Patients should be comfortable whatever their position. No information is available on the optimal time that a subject should remain in a particular position before a measurement, but three minutes is suggested for the lying and sitting positions and one minute standing. Some antihypertensive drugs cause postural hypotension, and when this is expected blood pressure should be measured both lying and standing.[1]

Arm support in standing position

Arm support

If the arm in which measurement is being made is unsupported, as tends to happen if the subject is sitting or standing, isometric exercise is performed raising blood pressure and heart rate. Diastolic blood pressure may be raised by as much as 10% by having the arm extended and unsupported during blood pressure measurement. The effect of isometric

exercise is greater in hypertensive patients and in those taking β blockers. It is essential, therefore that the arm is supported during blood pressure measurement and this is best achieved in practice by having the observer hold the subject's arm at the elbow, although in research the use of an arm support on a stand has much to commend it.[1]

Arm position

The arm must also be horizontal at the level of the heart as denoted by the midsternal 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 pressures. This source of error becomes especially important in the sitting and standing positions, when the arm is likely to be dependent by the subject's side. However, it has been demonstrated that even in the supine position an error of 5 mm Hg for diastolic pressure may occur if the arm is not supported at heart level.[1 2] Arm position has become an important issue for self measurement of blood pressure with the manufacture of devices for measuring blood pressure at the wrist, which are proving very popular because of the ease of measurement. Many of these devices are inherently inaccurate, but measurement is extremely inaccurate if the wrist is not held at heart level during measurement.

Which arm

This topic remains controversial as some studies, but not all, using simultaneous measurement have demonstrated significant differences between arms.[1] However, the fact that blood pressure differences between arms are variable makes the issue even more problematical. A reasonable policy is to measure blood pressure in both arms at the initial examination, and if differences greater than 20 mm Hg for systolic or 10 mm Hg for diastolic pressure are present on three consecutive readings the patient should be referred to a cardiovascular centre for further evaluation.

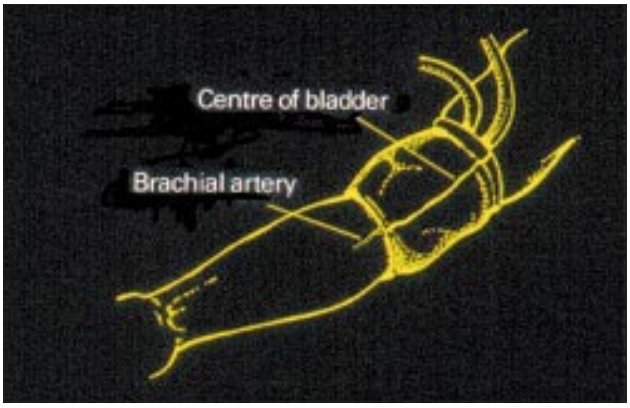
The cuff and bladder

The cuff is an inelastic cloth that encircles the arm and encloses the inflatable rubber bladder. It is secured around the arm most commonly by means of Velcro on the adjoining surfaces of the cuff, occasionally by wrapping a tapering end into the encircling cuff, and rarely by hooks. Velcro surfaces must be effective, and when they lose their grip the cuff should be discarded. It should be possible to remove the bladder from the cuff so that the latter can be washed from time to time.[1]

"Cuff hypertension"

However sophisticated a blood pressure measuring device may be, if it is dependent on cuff occlusion of the arm (as are the majority of devices), it will then be prone to the inaccuracy induced by miscuffing, whereby a cuff containing a bladder that is either too long or too short relative to arm circumference is used.

A review of the literature on the century-old controversy relating to the error that may be introduced to blood pressure measurement by using a cuff with a bladder of inappropriate dimensions for the arm for which it is intended has shown that miscuffing is a serious source of error, which must inevitably lead to incorrect diagnosis in practice and erroneous



Placement of cuff

Placement of stethoscope

Mismatching of bladder and arm

- Bladder too small — Overestimation of BP
  Undercuffing
- Bladder too large — Underestimation of BP
  Overcuffing

Undercuffing more common than *Overcuffing*

Recommended bladder dimensions. Data reproduced from O'Brien E, Petrie J, Littler WA et al. Blood Pressure Measurement: Recommendations of the British Hypertension Society. London: BMJ Books, 1997

Dimensions (cm)	Subject	Maximum arm circumference (cm)
4×13	Small children	17
10×18	Medium sized children	
	Lean adults	26
12×26	Majority of adult arms	33
12×40	Obese adults	50

Accurate readings may be obtained in adults with arm circumferences greater than 50 cm by placing a cuff with a 40 cm bladder so that the centre of the bladder is over the brachial artery. All dimensions have a tolerance of ±1 cm.

conclusions in hypertension research.[3] There is unequivocal evidence that either too narrow or too short a bladder (undercuffing) will cause overestimation of blood pressure, so called "cuff hypertension," and there is growing evidence that too wide or too long a bladder (overcuffing) may cause underestimation of blood pressure. Undercuffing has the effect in clinical practice of overdiagnosing hypertension and overcuffing leads to hypertensive subjects being diagnosed as normotensive. Either eventuality has serious implications for the epidemiology of hypertension and clinical practice.

A review of the literature shows that a number of approaches have been used over the years to cope with the difficulty of mismatching and none has been ideal. These have included application of correction factors, a range of cuffs, cuffs containing a variety of bladders, and a cuff for the majority of arms.

Recommended bladder length

A proposal for the future—the "Adjustable Cuff"

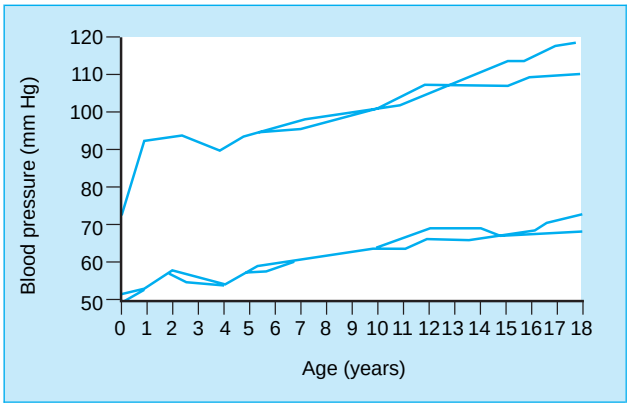
On the basis of a thorough examination of the literature and aware of the advances in cuff design, the design features for an "Adjustable Cuff," which would be applicable to all adult arms, have been proposed,[4] and one such cuff is presently undergoing testing (AC Cosor and Sons Ltd (Surgical), London, UK).

Blood pressure measurement in special subjects

Certain groups of people merit special consideration for blood pressure measurement, either because of age, body habitus, or disturbances of blood pressure related to haemodynamic alterations in other parts of the cardiovascular system. Although there is evidence that many subgroups of the hypertensive population may have peculiarities affecting the accuracy of measurement, such as patients with renal disease, patients with diabetes mellitus, women with pre-eclampsia, and youths with "spurious" hypertension, discussion will be confined to children, the elderly, obese subjects, and pregnant women.

Children

Blood pressure measurement in children presents a number of difficulties and variability of blood pressure is greater than in adults, and thus any one reading is less likely to represent the true blood pressure. Also increased variability confers a greater tendency for regression towards the mean. Conventional sphygmomanometry is recommended for general use, but systolic pressure is preferred to diastolic pressure because of greater accuracy and reproducibility. Cuff dimensions are most important and three cuffs with bladders measuring 4×13 cm, 10×18 cm, and the adult dimensions 12×26 cm are required for the range of arm sizes likely to be encountered in the age range 0-14 years. The widest cuff practicable should be used. Korotkoff sounds are not reliably audible in all children under one year and in many under five years of age. In such cases conventional sphygmomanometry is impossible and more sensitive methods of detection such as Doppler, ultrasound, or oscillometry must be used.[4]

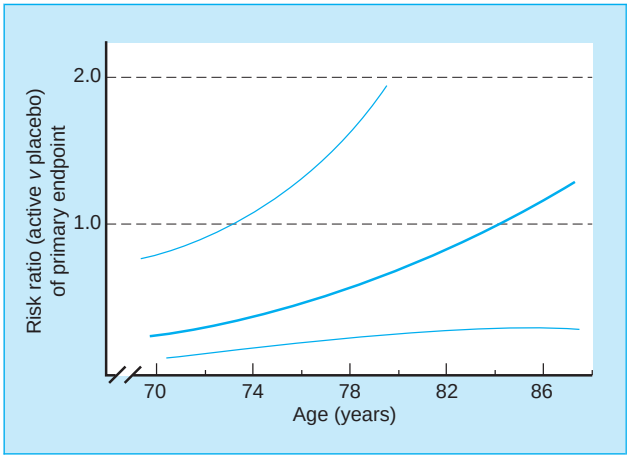


Mean systolic (top) and diastolic (bottom) blood pressures of boys and girls from birth to 18 years. Diastolic blood pressure reflects the use of phase IV Korotkov sounds. Reproduced with permission from de Swiet M, Dillon MJ, Littler W, O'Brien E, Padfield PL, Petrie JC. Measurement of blood pressure in children. Recommendations of a working party of the British Hypertension Society. BMJ 1989;299:469-70

Elderly people

In epidemiological and interventional studies blood pressure predicts morbidity and mortality in elderly people as effectively as in the young.[5] The extent to which blood pressure predicts outcome may be influenced by various factors that affect the accuracy of blood pressure measurement and the extent to which casual blood pressure represents the blood pressure load on the heart and circulation.[6]

The elderly are subject to considerable blood pressure variability, which can lead to a number of circadian blood pressure patterns that are best identified using ambulatory blood pressure measurement. The practical clinical consequence of these variable patterns in the elderly is that blood pressure measuring techniques can be inaccurate and/or misleading.



Epidemiological graph for the risk of hypertension in the elderly. Reproduced with permission from Dahloff B, Lindholm LH, Hansson L, Schersten B, Ekbom T, Wester PO. Morbidity and mortality in the Swedish Trial in Old Patients with Hypertension (STOP-Hypertension). *Lancet* 1991;394:405-12

Pseudohypertension

It has been postulated that as a consequence of the decrease in arterial compliance and arterial stiffening with ageing, indirect sphygmomanometry becomes inaccurate. This has led to the concept of "pseudohypertension" to describe patients with a large discrepancy between cuff and direct blood pressure measurement.[7] The significance of this phenomenon has been disputed,[8] but in elderly patients in whom blood pressure measured with the conventional technique seems to be out of proportion to the clinical findings, referral to a specialist cardiovascular centre for further investigation may be appropriate.

Overweight people

The association between obesity and hypertension has been known since 1923. The link has been confirmed in many epidemiological studies, and has at least two components.[9] Firstly, there appears to be a pathophysiological connection and it may well be that in some cases the two conditions are causally linked, and secondly, if not taken into account, it may result in inaccurate blood pressure values being obtained by indirect measurement techniques.

Obesity may affect the accuracy of blood pressure measurement in children, young people, the elderly, and pregnant women.

The relationship of arm circumference and bladder dimensions has been discussed above. If the bladder is too short, blood pressure will be overestimated—"cuff hypertension"—and, if too long, blood pressure may be underestimated.[3]

Arrhythmias

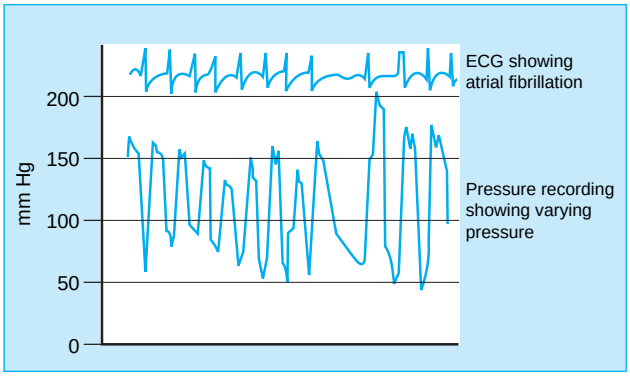
The difficulty in measuring blood pressure in patients with arrhythmias is that when cardiac rhythm is irregular there is a large variation in blood pressure from beat to beat. Thus in arrhythmias, such as atrial fibrillation, stroke volume and as a consequence blood pressure vary, depending on the preceding pulse interval. Secondly, in such circumstances, there is no generally accepted method of determining auscultatory endpoints. Furthermore blood pressure measuring devices vary greatly in their ability to accurately record blood pressure in patients with atrial fibrillation, indicating that devices should be validated independently in patients with arrhythmias.[10]

In bradyarrhythmias there may be two sources of error. Firstly, if the rhythm is irregular the same problems as with atrial fibrillation will apply. Secondly, when the heart rate is extremely slow, for example 40 beats per minute, it is important that the deflation rate used is less than for normal heart rates as too rapid deflation will lead to underestimation of systolic and overestimation of diastolic pressure.

Pregnancy

Clinically relevant hypertension occurs in more than 10% of pregnant women in most populations, and in a significant number of these raised blood pressure is a key factor in medical decision making in the pregnancy. Particular attention must be paid to blood pressure measurement in pregnancy because of the important implications for patient management, as well as the fact that it presents some special problems.[11]

There has been much controversy as to whether the muffling or disappearance of sounds should be taken for diastolic blood pressure. The general consensus from obstetricians based on careful analysis of the evidence is that disappearance of sounds (fifth phase) is the most accurate measurement of diastolic pressure, with the proviso that in those rare instances in which sounds persist to zero the fourth phase of muffling of sounds should be used.[12 13]



Blood pressure in atrial fibrillation

Taking blood pressure of a pregnant woman

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